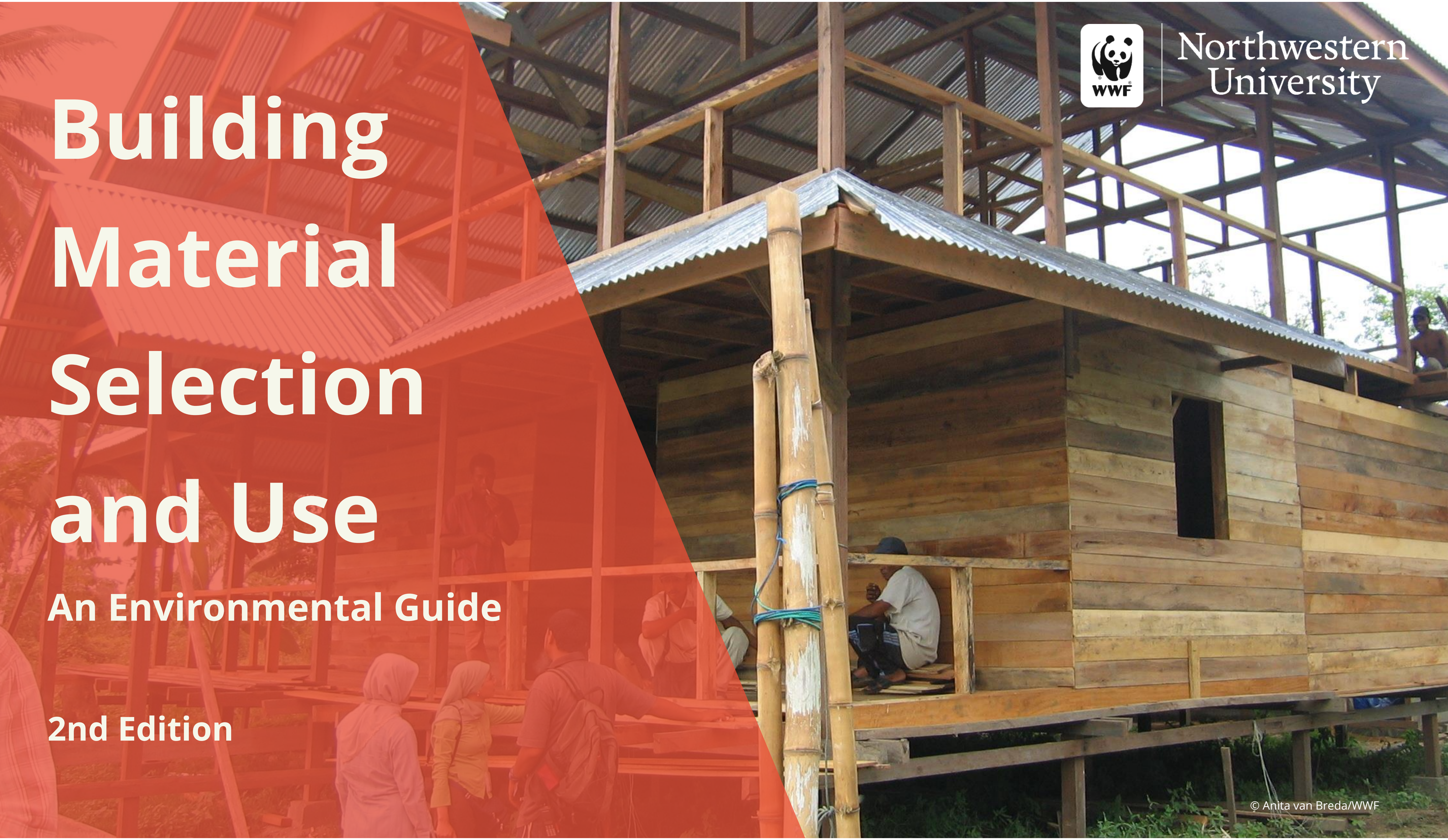

Northwestern University

Building Material Selection and Use

An Environmental Guide

2nd Edition

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INTRODUCTION

Increasing populations, rising urbanization, economic expansion, and the emergence of new industrial centers are among the driving factors increasing demand for construction material around the world. Building materials required for reconstruction after disasters have further added to growing demands. The exponential increase in material extraction, processing, and disposal can cause significant environmental and social impacts such as soil erosion, deforestation, landslides, and floods; deprive communities of essential livelihood resources; and put people, infrastructure, and ecosystems at greater risk of future disasters.

Practical guidelines for responsible construction material selection and use are rare. This guide aims to fill a gap and provide guidance on better practices for government agencies, private sector companies, NGOs, and community-based organizations (CBOs) for environmentally responsible selection, sourcing, use and disposal of construction material.

A large variety of construction materials are available in different regions of the world. If builders select and use materials in an environmentally responsible manner while also using responsible construction technology and practices, future construction needs can be met while creating a safe and secure built environment.

AIM

The aim of this document is to provide a general guideline for engineers, architects, project managers, and technicians in construction projects to select, source (or procure), and use specific building materials in an environmentally responsible manner. It is assumed that the user has a basic knowledge about building materials and the construction process, but it is not necessary to have advanced technical training to use this tool.

The guide provides information on environmental better practices related to design, planning, storage, use, and disposal for common building materials, as well as key environmental costs and benefits. Quantitative information such as embodied energy, CO_2 footprint, water usage and several other engineering properties are also provided for each material. The guide also introduces the user to some useful overall concepts for environmentally responsible selection and use of building materials throughout a construction project and material life cycles.

This guide provides only general environmental information for each material; the actual process of material selection and use requires careful professional judgment in each individual case.

PROJECT CYCLE AND MATERIALS

Materials-related decisions in construction projects are not made at one given time. Different issues are addressed in material selection, sourcing, procuring, storage, use, and disposal and emerge at different stages of the project cycle. Figure 1 displays the typical building material-related decisions that need to be made and environmental issues at different stages of the project cycle.

For example, material selection can substantially impact the cost of construction and project management. This decision has to be made at the beginning of the inception stage even before the detailed designs are done—e.g., bricks versus rammed earth walls. More detailed issues, such as using water-based paints instead of solvent-based paints, can be addressed later in the design or construction stages. Disposal of waste material is an issue that arises in the construction stage, but the reuse or disposal methods and sites should be identified well in advance of commencing construction.

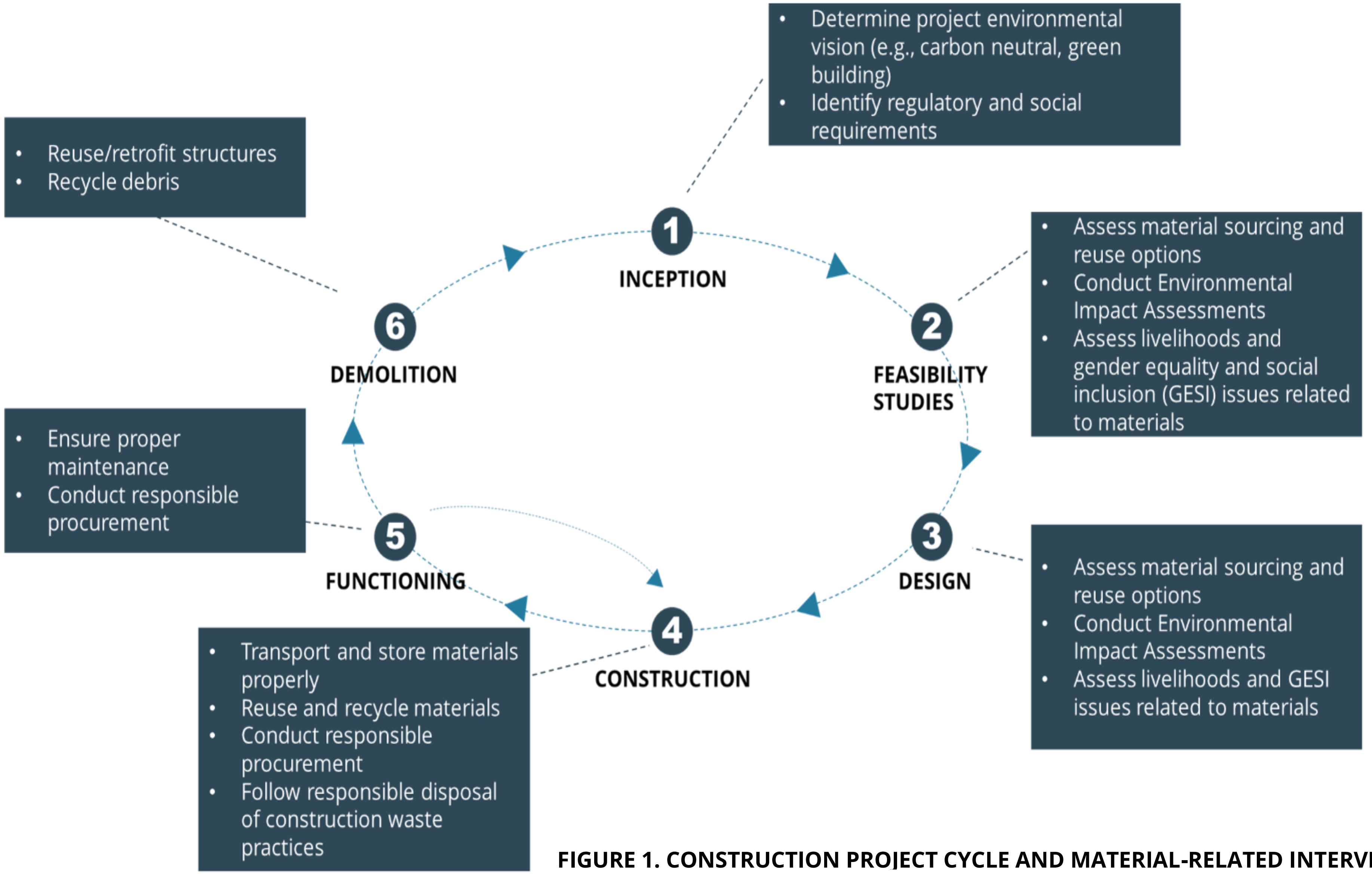

FIGURE 1. CONSTRUCTION PROJECT CYCLE AND MATERIAL-RELATED INTERVENTION POINTS

MATERIAL LIFE CYCLE

All materials come to the construction site through a process of extraction, transport, processing/manufacturing, packaging, and storage. Furthermore, the life of a material does not end after being used for construction; the structures are often demolished after a useful lifetime, and the materials are reused, recycled, repurposed, or disposed of. Some structures deteriorate with time, and the materials disintegrate into the environment. All these stages of the life cycle of a material may cause adverse environmental and social impacts.

Figure 2 displays the potential social and/or environmental impacts at different stages of a generic material life cycle.

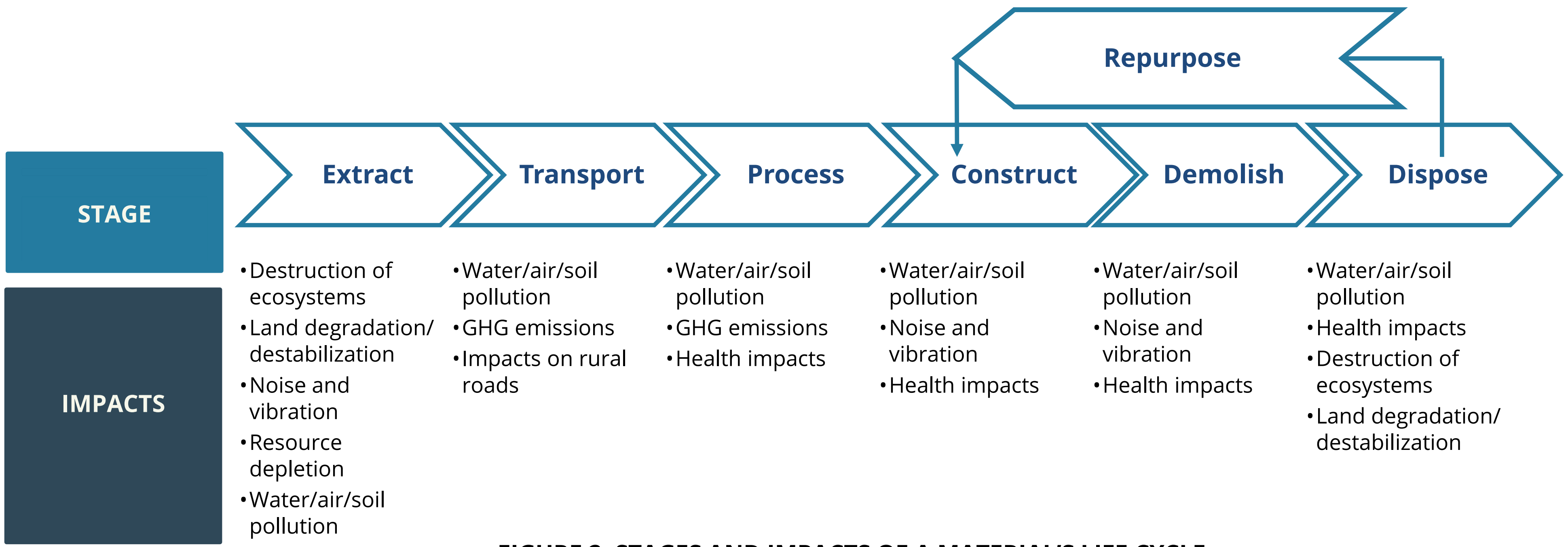

FIGURE 2. STAGES AND IMPACTS OF A MATERIAL'S LIFE CYCLE

RESPONSIBLE MATERIAL SELECTION AND USE: KEY CONCEPTS

1 **Think through the whole supply chain.** Environmental and social impacts from building materials can occur at any point in the supply chain, from sourcing raw materials, through processing and delivery to the site. This includes the social and environmental practices of manufacturers. For example, do working conditions at the processing plant meet responsible standards? Is the processing plant disposing of leftover material in an environmentally and socially responsible way?

The first criterion for an environmentally responsible material is the safety of the structure that will be built with it. "Not safe" is "not green."

2 **Only support sound and legal sourcing of materials.** In large-scale, post-disaster rebuilding, the demand for raw materials can quickly outstrip the supply of sustainably produced natural resources, such as clay for bricks, sand for cement, and wood for timber. For example, unsound excavation of clay or clear-felling of timber on steep hillsides to rebuild hundreds or thousands of houses increases the risk of landslides and topsoil erosion. Such environmental damage can increase risk and jeopardize the success of the overall recovery effort. Project managers should be aware of the sources of their building materials and make sure that they establish contract specifications for the use of sound and legally sourced materials. Using materials that have been credibly certified can be one strategy for ensuring that materials have been sourced sustainably. Material sourcing, processing, and use should be socially equitable. Any form of material sourcing that puts disproportionate burdens on women, children, differently abled or socially marginalized people is not sustainable. Furthermore, material sourcing should not disturb the established local livelihoods.

3 **Design to use fewer materials and reduce waste.** In designing structures, such as houses, project managers should consider ways to effectively meet humanitarian needs with fewer materials. Reducing packaging materials and designing structures with standard material sizes can help prevent waste of materials during the transportation and construction phases. Designing structures and specifying materials for optimal design rather than either overengineering or creating rigid requirements can reduce material waste by allowing some flexibility in construction and in material options. For example, if one material or size is not available locally, another can be used in its place to achieve optimal design instead of importing additional materials to fit a very specific requirement. Following material-specific storing and handling guidelines also helps extend the shelf life of materials and ensures that materials are not damaged and will not need to be replaced.

4 **Use local sources—where this can be done in an environmentally responsible way.** Local procurement of materials can be a more environmentally sound strategy than the procurement of distant materials because of reduced carbon emissions from transportation and natural resource use in packaging. Give priority to materials selected or processed with traditional knowledge. When using local materials, however, project managers should make sure that extraction, processing, and use do not put people's health or environment at risk.

5 **Use disaster debris as a reconstruction material.** One of the most environmentally sustainable options for construction projects in a post-disaster setting is the reuse of building materials found in disaster debris. If using disaster debris, project managers must ensure that the debris meets applicable specifications for strength and safety.

6 **Use materials with recycled content and recycle.** Materials with recycled content are widely available. One example is cement produced with fly ash from coal-fired power plants. Project managers should consider using building materials with recycled content where practical to reduce demand on natural resources and lower the project’s human and environmental impacts. Leftover material or material packaging should also be considered for reuse, repurposing, and/or recycling.

ACRONYMS

ABC	Aggregate Base Concrete
ACI	American Concrete Institute
BRE	Building Research Establishment
CBO	Community-based Organization
CGI	Corrugated Galvanized Iron
CSEB	Compressed Stabilized Earth Block
GESI	Gender Equality and Social Inclusion
HSE	Health and Safety Executive
NGO	Nongovernmental Organization

Definitions

CO_2 Footprint

In Table 1, we provide CO_2 footprint values for each material. We define CO_2 footprint as the CO_2 released per unit weight of finished material, including all the steps involved in obtaining, purifying, processing, transporting, and shaping each material into finished articles. CO_2 footprint values may not reflect locally-specific greenhouse gas emissions because, depending on location, supply chain and manufacturing methods may vary. Therefore, these values will serve as rough approximations rather than exact values.

Embodied Energy

In Table 1 we provide values for the energy expended in obtaining, purifying, processing, transporting, and shaping each material into finished articles. Embodied energy values may not reflect locally-specific values because, depending on location, supply chain and manufacturing methods may vary. Therefore, these values will serve as rough approximations rather than exact values.

Water Usage

In Table 1 we provide values for the water consumed while obtaining, purifying, processing, and shaping each material into finished articles. Water consumption values may not reflect locally-specific values because, depending on location, supply chain and manufacturing methods may vary. Therefore, these values will serve as rough approximations rather than exact values.

Table 1: ENVIRONMENTAL GUIDE TO SELECTION OF COMMON BUILDING MATERIALS

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A. General Construction Material						
A1	River sand	Types of Use Concrete, Cement mortar, Plaster (as a bedding material), Asphalt *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy 0.06 MJ/Kg CO_2 Emissions 0.004 Kg/Kg Water Usage 3.60 l/Kg	**Extraction** Erodes channel bed and banks, increases channel slope, and leads to changes in channel morphology. These impacts may cause: • undercutting and collapse of riverbanks • loss of adjacent land and/or structures • upstream erosion • downstream erosion • downstream changes in patterns of deposition • destruction of riverine habitats **Transport** Transport using large trucks affects rural roads and may cause noise and air pollution. **Production/Treatment** None **Toxicity** None **Benefits** None	Manufactured sand (crushed rock/gravel), Sea sand, Crushed rubble (debris), Fly ash/bottom ash, Recycled building and quarry dust	• Use alternatives to concrete/ mortar, e.g., stabilized earth walls (refer to section B) • Use premixed concrete instead of in-situ mixing • Use prefabricated concrete items • Optimize concrete mix design to reduce material and energy requirements • Use standardized bricks to minimize mortar and plaster	**Storage** Store in a manner free from contamination by other site materials, for example, by providing containment with proper base and curb. Protect from rain and other water sources. **Use** Adhere to the building specifications for mixing mortar and concrete and building. Overuse of the material will not add additional strength, and will cause waste. Mix in small adequate batches to minimize waste. Do not mix more fresh concrete/mortar than you will use in a two-hour period. **Disposal** Never dispose of washout cement, sand, cement mortar, or concrete in environment. They can be • reused on-site/off-site for construction purposes (e.g., filling), • safely transported to a construction material recycling facility, or • safely transported to a sanitary landfill

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A2	River gravel/ boulders *[diverse rock minerals]*	Concrete, Random rubble masonry, Aggregate base concrete (ABC), Road base, Manufacturing sand, Asphalt *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 7.8 - 8.7 CO_2 footprint (kg/kg): 0.027 - 0.030 Water usage (l/kg): 3.85 – 4.17	**Extraction** Same as A1 **Transport** Transport using large trucks affects rural roads and may cause noise and air pollution. **Production/Treatment** Process often involves crushing into uniform sizes or fines (sand). Crushing plants cause noise, air pollution, silting of water bodies/ wetlands etc. **Toxicity** None **Benefits** In highly sediment or blocked streams, removal of river gravel and boulders may restore the flow.	Crushed rock, Crushed rubble (debris)	• Plan and design construction to minimize waste • Use alternatives to concrete/ mortar, e.g., stabilized earth walls • Use premixed concrete instead of in-situ mixing • Use prefabricated concrete items	**Storage** Locate stockpiles to provide safe access for withdrawing material. **Use** Refer to A1 **Disposal** Refer to A1

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A3	Quarried rock	Concrete, Random rubble masonry, Aggregate base concrete (ABC), Road base, Manufactured sand, Asphalt *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 6.43 - 6.69 CO_2 footprint (kg/kg): 0.48 - 0.53 Water usage (l/kg): 13.0 - 14.4	**Extraction** Extraction from quarries involves blasting. Quarries cause noise, dust, air pollution, habitat destruction, and vibration if not properly managed. Unplanned rock quarrying can cause landslides and hydro-geological impacts. Without planning and protection blasting causes occupational hazards. **Transport** Transport using large trucks affects rural roads and may cause noise and air pollution. **Production/Treatment** Process often involves crushing into uniform sizes or fines (sand). Crushing plants cause noise, air pollution, silting of water bodies/wetlands etc. **Toxicity** None **Benefits** None	Crushed concrete, Broken brick (for certain uses only)	• Use optimum mix design to minimize the quantity of quarried rock used • Select a quarry site close to the construction site to minimize distance of transportation • Consider mixing with recycled material (crushed concrete or broken brick) in design • Measures should be taken to prevent over-extraction.	**Storage** Locate stockpiles to provide safe access for withdrawing material and ensure minimum spill and waste. **Use** Refer to A1 **Disposal** Refer to A1

A4	Ordinary Portland Cement (OPC) *[63% CaO, 21% SiO_2, 6% Al_2O_3 + additions]*	Concrete, Mortar, Plaster, Stabilized earth construction/ blocks *[consistent quality, predictable structural strength]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 7.75 – 8.60 CO_2 footprint (kg/kg): 1.08 - 1.20 Water usage (l/kg): 35.1 - 38.8	**Extraction** Uses limestone and other minerals extracted from quarries or mines in manufacturing, which can cause severe mining impacts. **Transport** Transport using large trucks affects rural roads and may cause noise and air pollution. **Production/Treatment** Produces greenhouse gases both, directly through the production of carbon dioxide when calcium carbonate is heated (producing lime and carbon dioxide), and indirectly through the use of energy, particularly if the energy is sourced from fossil fuels. **Toxicity** None **Benefits** None	Lime mortar, Other cement-derived material (not suitable for concrete)	• Use alternatives to concrete/mortar, e.g., stabilized earth walls • Use premixed concrete instead of in-situ mixing • Use prefabricated concrete items • Optimize concrete mix design (don't over-specify) • Use standardized bricks/blocks to minimize mortar and plaster • Use precast concrete designs for construction; precast concrete can be designed to optimize (lessen) the amount of concrete used in a structure or element	**Storage** Store cement in a building that is dry, leak-proof, and as moisture proof as possible. There should be a minimum number of windows in the storage building. Stack the cement bags off the floor on wooden planks in such a way, so that bags are about 150 mm to 200 mm above the floor. **Use** Use quantities as specified in the optimum mix design. Avoid wastage by calculating adequate hauling times when purchasing premixed concrete and use retarders in case of long hauls. Do not mix more fresh concrete or cement than you will use in a two-hour period. Also refer to A1 **Disposal** Refer to A1 Never dispose of cement slurry or washout in streams or street drains. Never dispose of empty cement bags in the environment. Instead, dispose of them in a sanitary landfill. Never dispose of washout cement, sand, cement mortar, or concrete in environment. They can be: • Reused on-site/off-site for construction purposes (e.g., filling),

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
						• Safely transported to a construction material recycling facility, or • Safely transported to a sanitary landfill

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A5	Stone (e.g., granite, gneiss, sandstone, basaltic rocks)	Concrete, Random rubble masonry, aggregate base concrete (ABC), Manufacturing sand, asphalt, walls *[Building and cladding, used for high performance or vibration sensitive equipment]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 7.74 - 8.71 CO_2 footprint (kg/kg): 0.55 – 0.64 Water usage (l/kg): 3.23 - 3.57	**Extraction** Refer to A1 **Transport** Refer to A1 **Production/Treatment** Process often involves crushing into uniform sizes or fines (sand). Crushing plants cause noise, air pollution, silting of water bodies/wetlands etc. **Toxicity** None **Benefits** None	Recycled debris	• Plan and design construction to minimize waste • Use alternatives to concrete/mortar, e.g., stabilized earth walls • Use premixed concrete instead of in-situ mixing • Use prefabricated concrete items	**Storage** Locate stockpiles to provide safe access for withdrawing material. **Use** Refer to A1 **Disposal** Refer to A1

A6	Concrete (different Grades) *[Water: OPC : Fine aggregate (sand): Coarse aggregate]*	Walls, Foundation, Roofing *[Has good compressional strength, but not good under tension. Hence, there is a need for reinforcement with steel bars/ timber or bamboo* *If 30% coarse recycled aggregates are used, 17% lower elastic modulus is obtained, which makes concrete still usable depending on the desired strength requirements.* *Lowering water to cement ratio helps in reducing permeability (can be used in areas having high rainfall)*] **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 3.16 - 3.58 CO_2 footprint (kg/kg): 0.24 - 0.27 Water usage (l/kg): 3.23 - 3.57	**Extraction** Refer to A1 to A5 **Transport** Refer to A1 to A5 **Production/Treatment** Refer to A1 to A5 **Toxicity** Refer to A1 to A5 **Benefits** Refer to A1 to A5	Stabilized earth blocks or walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	• Use alternatives to concrete/ mortar, e.g., stabilized earth walls (refer to section B) • Use premixed concrete instead of in-situ mixing • Use prefabricated concrete items • Optimize concrete mix design (don't over-specify) (BRE mix design, ACI method of concrete mix design) • Use standardized bricks to minimize mortar and plaster	**Storage** Refer to A1 **Use** Refer to A1 **Disposal** Refer to A1 Recyclable, Downcycle. Landfill, non-biodegradable, non-toxic, not a renewable source **Reuse:** Can be directly re-used during land rehabilitation, concrete can be crushed manually and re-used as filler for abandoned pits, drainage trenches and other surface irregularities. This also provides local income. Should never be directly re-used for structural purposes. **Recycle** Concrete can be crushed and recycled as aggregate or for building and road base material or foundation bedding etc. Concrete can be crushed manually; with a mobile crushing unit or transported to a specialised concrete crushing plant. Location, volume of concrete waste, local demand for aggregates and availability of other types of aggregates are determining factors in the choice of crushing method. If the concrete is reinforced, material such as steel rebar may block crushing machines if they are

						not designed to separate the steel from the concrete. Proper assessment must take place to ensure no asbestos is present prior to crushing.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A7	Concrete (insulating, lightweight) *[Water: OPC: sand: lightweight coarse aggregate – e.g., shale, slate, clay]*	Refer to A6 *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 1.60 – 1.76 CO_2 footprint (kg/kg): 0.177 - 0.128 Water usage (l/kg): 14.3-15.8	Refer to A6	Refer to A6	Refer to A6	Refer to A6

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A8	Aerated concrete (low density) *[Water: OPC: Foam or chemically induced gas bubbles: fine filler – crushed sand]*	Walls, Roofing, Sound insulation, Fire resistance *[None]* *[As compared to ordinary concrete, aerated concrete has a lower density, hence it is lightweight and provides intentionally entrained air voids to improve resistance to freezing and thawing in moist areas.* *Easy to nail, shape and render, but it has low wear resistance.]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 1.73 - 1.86 CO_2 footprint (kg/kg): 0.187 - 0.207 Water usage (l/kg): 14.30 - 15.80	Refer to A1 to A5	Stabilized earth blocks or walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	Refer to A6	**Storage** Refer to A1 **Use** Refer to A1 **Disposal** Refer to A6

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A9	High volume fly ash concrete *[(0.8:1:1:4.67:1.33:5) Water, Ordinary Portland Cement, Fly ash, Coarse sand, Gravel, Rock]*	Walls, Foundation, Roofing *[Fly ash makes the concrete stronger, more durable and easier to work with]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 6.09 – 6.73 CO_2 footprint (kg/kg): 0.116 - 0.128 Water usage (l/kg): 3.23 - 3.57	Refer to A1 to A5	Stabilized earth blocks or walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	Refer to A6	**Storage** Refer to A1 **Use** Refer to A1 **Disposal** Refer to A6
A10	Latex concrete *[0.8:1.1:1:1:4.67:1.33 :5 Water, Latex admixture, Ordinary Portland Cement, Fly ash, Coarse sand, Gravel, Rock]*	Walls, Foundation, Roofing *[Makes the cement highly moisture resistant, highly durable]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 6.09 – 6.73 CO_2 footprint (kg/kg): 0.116 - 0.128 Water usage (l/kg): 3.23 - 3.57	Refer to A1 to A5	Stabilized earth blocks or walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	Refer to A6	**Storage** Refer to A1 **Use** Refer to A1 **Disposal** Refer to A6

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A11	Polyvinyl Alcohol (PVA) and cellulose fiber-cement *[2-4% PVA, 8-10% cellulose, 10-15% carbonate filler, 4-6% silica fume, 65-70% OPC (% by volume)]*	Walls, Foundation, Roofing *[PVA fibers increase flexural and compressive strength properties of concrete]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 6.09 – 6.73 CO_2 footprint (kg/kg): 0.116 - 0.128 Water usage (l/kg): 3.23 - 3.57	**Extraction** High energy consumption to extract cellulose from plant materials **Production/Treatment** High energy consumption and cost **Toxicity** None **Benefits** Non-hazardous, cellulose is a renewable material	Stabilized earth blocks or walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	Refer to A6	Refer to A6

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A12	Polypropylene Fiber-Reinforced Concrete *[<0.5% polypropylene fibers by volume, OPC, fine aggregate]*	Walls, Foundation, Roofing *[Polypropylene fibers reduce shrinkage and temperature cracking and increase toughness and impact resistance]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 6.09 – 6.73 CO_2 footprint (kg/kg): 0.116 - 0.128 Water usage (l/kg): 3.23 - 3.57	Refer to A1 to A5	Asbestos concrete, Stabilized earth blocks or walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	Add fibers to concrete mix at the site if it takes more than 30 minutes to get to the site. Refer to A6	Refer to A6

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A13	Cellulose Fiber-Reinforced Concrete *[0.2-0.5% cellulose by weight]*	Walls, Foundation, Roofing *[Cellulose can be obtained from agricultural waste, wood, plants.* *Cellulose fibers are used for the control and mitigation of plastic shrinkage cracking]* **Embedded Energy/CO2 Footprint** Embodied energy (MJ/kg): 6.09 – 6.73 CO_2 footprint (kg/kg): 0.116 - 0.128 Water usage (l/kg): 3.23 - 3.57	Refer to A1 to A5	Asbestos concrete, Stabilized earth blocks or walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels Alternatives to cellulose: Synthetic fibers, Steel reinforcing bars	Refer to A6	Refer to A6

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A14	Glass Fiber reinforced composite (GFRP) *[Epoxy + glass fiber reinforcement]*	Reinforcing concrete *[Can be used as an alternative to steel rebar. Enhances strength significantly]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 115 – 129 CO_2 footprint (kg/kg): 7.17 – 7.80 Water usage (l/kg): 212 - 240	**Extraction** Manufactured using glass fiber and epoxy. Refer G3 and E3 **Production/Treatment** Refer G3 and E3 **Toxicity** Refer G3 and E3 **Benefits** Non-corrosive, high strength	Steel rebar, Natural reinforcing materials	Use only in special cases where steed or natural forms of reinforcement is not applicable. The environmental costs of GFRP are generally higher. Design carefully to minimize overuses, do not over specify. Minimize cutting at site.	**Storage** Store in place protected from extreme weather and fire. Refer E3 **Use** Refer G3 and E3 **Disposal** Cannot be recycled, non-biodegradable, non-renewable, cannot be combusted for energy. Can be put in landfill or downcycle

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
A15	Low carbon steel *[<0.3% carbon content]*	Reinforcing concrete. Used in bars of different diameters, for columns, beams, slabs and structural walls of building. Also used in reinforcing foundations. Available in different standard diameters (e.g. 6mm, 10 mm, 12mm, 16mm, 20mm). Made in mild or yield steel of compressive strength grade 250 N/mm^2. *[Surface treatment by: Carburizing, pickling, zinc or zinc-nickel pickling, phosphate or chromate treatments, galvanization and passivation.]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 35.8 – 39.6 CO_2 footprint (kg/kg): 2.53 – 2.80 Water usage (l/kg): 43.2 - 47.7	**Extraction** Requires large scale extraction of iron ore, causing significant environmental impacts including deforestation, land degradation, and hydrological modifications. High energy consumption and greenhouse gas (GHG) emissions, in extraction and transport. Mining often releases toxic and pollutive minerals. **Production/Treatment** Smelting of iron ore and forging and drawing of steel bars is highly energy intensive and releases massive quantities of GHGs. Produces potentially hazardous waste material, which can be damaging health and environment, if not properly managed. **Toxicity** None **Benefits** Commonly available, easily recyclable into other steel products	GFRP, Natural reinforcing materials	• Use certified products and avoid using in corrosive environments • Avoid contact with ground or high levels of moisture • Encourage reuse of uncorroded sheets from old buildings • Use standard sizes	**Storage** Store in a dry place **Disposal** Will have lost its some of its structural properties during use. Recycle, downcycle, landfill. Non-biodegradable, cannot be combusted for energy, non-renewable

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	B. Wall Material					

B1	Burnt brick (common) *[Made of fired clay, with impurities of potash, lime, soda and oxides of iron (which is responsible for imparting the red color) and aluminum]*	Walls, Columns, Foundations, Floor paving *[Most bricks are porous and are glazed if they need to resist water. To do this, the surface of the fired brick is painted with a mixture of glass-forming fluxes. The brick is then fired again, which melts the glaze, and forms a glassy surface on the brick.* *Engineering brick is used where high strength, low porosity, and high frost resistance are required. Common brick is used where appearance is not important, or where it will be rendered/plastered.]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 11.9 - 15.7 CO_2 footprint (kg/kg): 0.75 – 1.03 Water usage (l/kg): 5.27 - 5.83	**Extraction** Mining of surface clays, shales, and some fire clays occurs in open pits with power equipment; then the mixtures require transport to plant storage areas. **Transport** Transport using large trucks affects rural roads and may cause noise and air pollution. **Production/Treatment** Brick firing is an energy-intensive process. The brick industry is therefore one of the largest consumers of firewood and coal and, hence, is also a significant air polluter. Air pollution and the use of good-quality agricultural soil are the major environmental concerns related to the use of bricks. Brick kilns may emit toxic fumes (suspended particulate matter, carbon monoxides, and oxides of sulphur—SO_X) that are harmful to eyes, lungs, and throat. **Toxicity** None **Benefits** None	Cement blocks, Stabilized earth blocks, Stabilized earth walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	• Produce bricks on-site (e.g., stabilized earth blocks) • Encourage reuse of bricks from demolished buildings • Use standardized, quality-controlled bricks for construction • Reduce wastage by accurately estimating brick requirement • Use standard lengths and optimal wall thicknesses in design to minimize brick waste	**Storage** Properly package/load bricks during transport and store in a dry place in suitable stack heights. **Use** Not significant **Disposal** Never dispose of bricks/blocks in streams, wetlands, coastal areas or agricultural lands. Non-biodegradable, cannot be combusted for energy recovery, can be downcycled or put in landfill. **Reuse** Bricks/blocks in sound condition can be directly reused for on-site/off-site construction purposes (e.g. walls), if damaged can be used for filling or paving. They can be resold to the community and/or re-used in reconstruction programs. The presence of cement mortar or glues can hinder re-use as they are unable to be cleaned off. **Recycle** Safely transport to a construction material recycling facility. Can be recycled into coarse aggregate, fillers, base, paving material, or landscaping applications.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
B2	Cement blocks *[Refer to A6]*	Walls *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 7.75 – 8.60 CO_2 footprint (kg/kg): 1.08 -1.20 Water usage (l/kg): 35.10 - 38.80	**Extraction** Requires cement, quarried and mined material (e.g., sand, rock chips, and gravel). (see A1, A2, A3, and A4) **Transport** Transport using large trucks affects rural roads and may cause noise and air pollution. **Production/Treatment** Manufacturing uses power or manually operated pressure moulds. Casting yards can cause dust, noise and silt problems. **Toxicity** None **Benefits** • No firewood demand • Minimal air pollution	Stabilized earth blocks, Stabilized earth walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	• Use standardized and good quality blocks for construction • Use accurate estimates to purchase blocks—this will minimize wastage • Produce concrete blocks on-site • Ensure quality control in manufacturing and use standard lengths and optimal wall thicknesses in design to minimize brick waste • Use proper packaging/loading practices in transporting	**Storage** Refer to B1 **Use** Not significant **Disposal** Refer to B1 **Reuse** Refer to B1 **Recycle** Refer to B1. Apart for landscaping applications.

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				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
B3	Compressed stabilized earth blocks/ CSEB *[5% cement, 95% mud (compressed into blocks) (by vol)]*	Walls *[not suitable for high-moisture environments or load-bearing walls, unless tested specified by a structural engineer]*	**Extraction** Requires soil with small amounts of sand and cement. Soil extraction can cause habitat destruction and landslides and can pollute water bodies and alter hydrology. **Transport** Transport using large trucks affects rural roads and may cause noise and air pollution. **Production/Treatment** Manufacturing uses power or manually operated pressure molds. Casting yards can cause dust, noise and silt problems. **Toxicity** None **Benefits** • No firewood demand • Minimal air pollution • Minimal demand for quarried material • Minimal transport requirement	Stabilized earth walls, Straw clay walls, Bamboo/timber reinforced earth walls, Prefabricated wall panels	• Design the building to match available block dimensions • Produce CSEB on-site with proper quality control, this will reduce the cost of transportation and production	**Storage** Refer to B1 **Use** Not significant **Disposal** Refer to B1

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives: Potential Material Alternatives	Management & Alternatives: Environmental Better Practices (Design/Planning)	Management & Alternatives: Environmental Better Practices (Storage/Use/Disposal)
B4	Earth walls (stabilized earth, clay-straw, rammed earth, bamboo reinforced earth) *[stabilized earth, claystraw, rammed earth, bamboo reinforced earth; 75%-85% soil (40%-70% sand, 10%-20% clay, 30%-60% gravel), 6%-10% cement, 9.5% - 11% water]*	Walls *[not suitable for high-moisture environments or load-bearing walls, unless tested specified by a structural engineer]*	**Extraction** Requires soil with small amounts of sand and cement. Soil extraction can cause habitat destruction and landslides and pollute water bodies and alter hydrology. **Transport** Transport requirement is minimal. **Production/Treatment** Fabricating is in-situ using wooden or steel formwork and soil/clay. **Toxicity** None **Benefits** • No fire wood demand • No air pollution • No demand for quarried material • Minimal transport requirement • Readily available in tropical climates, particularly in Sri Lanka*	Straw clay walls, Bamboo/timber-reinforced earth walls, Prefabricated wall panels	• Match available steel or wood formwork dimensions with the structural dimensions of the building • Reduce construction time with proper planning • Use only in areas where earth can be extracted without causing hazards or environmental impacts • Use standard lengths and optimal wall thicknesses • Allow for sufficient curing time (4 days) to accommodate drying, shrinkage, and cracking	**Storage** Store soil in a dry, enclosed space. **Use** Use optimum mix proportions and only mix in small and adequate batches. **Disposal** Never dispose of demolished wall material in streams, wetlands or coastal areas. **Reuse:** Reuse demolished walls material for on-site/off-site construction.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
	C. Timber					

<table>
<tr><th rowspan="2">Item No.</th><th rowspan="2">Material
[composition]</th><th rowspan="2">Technical Information
[special technical remarks]</th><th rowspan="2">Environmental Costs / Impacts / Benefits</th><th colspan="3">Management & Alternatives</th></tr>
<tr><th>Potential Material Alternatives</th><th>Environmental Better Practices (Design/Planning)</th><th>Environmental Better Practices (Storage/Use/Disposal)</th></tr>
<tr><td>C1</td><td>Forest timber

[Cellulose, Hemicellulose, Lignin, 12% water]</td><td>Roof structure, Beams, Columns, Door and window frames, Decks, Floor paving, Roof tiles, Wall panels, Formwork

[None]

Embedded Energy/CO_2 Footprint

Embodied energy (MJ/kg): 10.4 -11.6
CO_2 footprint (kg/kg): 0.885 - 0.978
Water usage (l/kg): 665 - 735</td><td>**Extraction**
Extraction can cause forest destruction, landslides, land degradation, and habitat destruction and can increase flood risk.

Transport
Transport of logs can further damage forests and rural roads.

Production/Treatment
Processing takes place in timber mills. Mills that are poorly managed cause solid-waste pollution and noise and air pollution.

Toxicity
Requires treatment for pest control. Using toxic chemicals for treatment causes environmental and health hazards.

Benefits
• A renewable resource, if well managed</td><td>Farmed timber, Plywood, Fiber boards, Bamboo</td><td>• Do not over design/over specify— where possible, conduct proper structural design for timber buildings and calculate the timber need accordingly
• Minimize cutoffs
• Treat timber properly for long term durability
• Minimize the use of timber for formwork and use reusable modular formwork instead</td><td>**Storage**
Store timber as close as practicable to your site. Properly store in a covered dry place, with proper stack heights. Allow air circulation and support well to avoid sagging. Keep it away from moisture as much as possible.

Use
Schedule timber delivery in-line with the phase of the project when it will be required to prevent unnecessary exposure of timber to the elements.
Take extra care when handling to ensure that products are not spoiled while being moved.
Use protection when handling and cutting chemically treated timber.

Disposal
Encourage timber reuse (e.g., door and window frames, roof members).
Never dispose of timber in streams, wetlands, or coastal areas.
Chemically treated timber trimmings should be considered a hazardous material; never use as firewood.
Renewable resource, biodegradable
Downcycle, combust for energy, landfill.</td></tr>
</table>

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
						Reuse Wood can be reused for a variety of different purposes, ranging from low-quality, temporary work like survey pegs and boxing for concreting, to high-quality, permanent uses like floor boards, beams, and other architectural features if the recovered material is in a suitable condition. Depending on the type of disaster, rotting, humidity, or splitting, presence of nails or screws can affect the potential for reuse. **Recycle** Untreated timber off-cuts can be chipped into mulch and used in landscaping, animal bedding or used as fuel. Depending on the context, wood from construction and demolition waste competes with forestry and manufacturing wood waste as an input for industrial furnaces and boilers, particularly in pulp and paper mills.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
C2	Farmed timber *[Refer to C1]*	Roof structure, Beams, Columns, Door and window frames, Decks, Floor paving, Roof tiles, Wall panels, Formwork *[None]* Refer to C1	Same as C1 **Benefits** • A renewable resource, if well managed • Minimal impact on natural forests • Over-extraction can be managed	Forest timber, Plywood, Fiber boards, Bamboo	• Refer to C1	Refer to C1

C3	Plywood/ laminated panels, Chip boards, Fiber boards *[Cellulose/Hemicellulose/Lignin/ 12% water/ adhesive]*	Wall panels, Floor panels, Formwork, Partition walls, Insulation *[only suitable for temporary use in external work.* *Properties depend on moisture content.* *Plywood is made from multiple layers of thin solid wood glued together to form a panel of a specific thickness. The plies are oriented so that the grain direction in one ply is rotated 90° relative to adjacent plies. This enhances both the strength and dimensional stability of the plywood. Plywood over 10mm thick is almost equal in strength in both directions as opposed to solid wood.]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 34.5 -38.0 CO_2 footprint (kg/kg): 2.23 – 2.45 Water usage (l/kg): 665 - 735	**Extraction** Extraction can cause forest destruction, landslides, land degradation, and habitat destruction and can increase flood risk. **Transport** Transport of logs can further damage forests and rural roads. **Production/Treatment** Manufacturing uses timber mill by-products or farmed soft wood and chemical binders. It takes place in large factories with energy-intensive processes. Processing results in air pollution. (see C1) **Toxicity** Using binding material and treatment chemicals in manufacturing can cause environmental and health hazards. **Benefits** • Minimal impact on natural forests • Uses timber mill by-products • Ability to be pre-formed into efficient sizes and thicknesses	Engineered bamboo (Woven bamboo panels, laminated bamboo, bamboo scrimber)	• Refer to C1 • Design to use standard panel sizes (minimize trimming)	**Storage** Refer to C1 **Use** Refer to C1 **Disposal** Refer to C1 Downcycle, combust for energy, landfill, biodegradable. Cannot be recycled.
C4	Bamboo *[Refer to C1]*	Roof structure, Woven wall panels, partitioning, Concrete reinforcement	**Extraction** Extracted from natural or farmed bamboo groves. Unmanaged	Timber	• Use only when sustainable harvesting is possible • Have a harvesting plan	**Storage** Ensure storage in a good place, with proper stack heights. Allow air

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
		[Properties depend strongly on moisture content, needs protective coating to protect from moisture and attack from insects and termites (Borax coating, resins, adhesives)] **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 21.7 - 24.0 CO_2 footprint (kg/kg): 1.63 -1. 80 Water usage (l/kg): 6.65 - 7.50	extraction may cause habitat destruction, riverbank degradation **Production/Treatment/Toxicity** Usually used directly without any processing. However, bamboo can be processed into high-quality products such as panels and mats. Some products require energy intensive factory processes. These processes may cause air and water pollution if not properly managed. **Benefits** • Fast growing and renewable (fastest growing woody plant). • Minimum impact on natural forests, unless forests are removed to plant bamboo. • Supports indigenous livelihoods and knowledge. Can be a substitute for slower growing timber. Bamboo stabilizes the earth with its roots, preventing erosion. Regrows from shoots; no need for replanting • Rapidly renewable. Mechanical properties similar to timber • Sustainable • Cost effective		• Encourage reuse in formwork • Treat for long term durability and procure value-added products from local industries (use natural seasoning or non-toxic certified treatment chemicals. Borax or boric acid treatment is common, though should be carried out with care and training, as both chemicals have proven health hazards).	circulation. Support well to avoid sagging **Use** Refer to C1 **Disposal** Renewable resource, biodegradable Downcycle, combust for energy, landfill **Recycle:** Other uses include compost or chip. Dry and use as fuel.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
C5	Bamboo scrimber (bamboo fiber based, composite manufactured timber) *[Bamboo + phenol formaldehyde resin]*	Roof structure, Woven wall panels, partitioning, Formwork props, Scaffolding *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 21.7 – 12.3 CO_2 footprint (kg/kg): 1.63 – 1.80 Water usage (l/kg): 6.65 - 7.50	**Extraction** Refer to C4 **Production/Treatment/Toxicity** Might require energy intensive factory processes to make the scrimber strong. These processes may cause air and water pollution if not properly managed. Formaldehyde resins used in manufacture is identified as potential human carcinogen. Therefore, long term exposure to dust or inhalation of fumes while burning this material can be hazardous. **Benefits** • Less moisture content than bamboo, highly moisture resistant • Much more resistant to termites, mold attacks, adverse climate conditions • Comparable mechanical properties to timber and bamboo • Higher flexural strength than other natural composites	Timber, raw bamboo	Refer to C4	**Storage** Refer to C4 **Use** Refer to C1 **Disposal** Renewable resource, not biodegradable. Combustion for energy is not recommended. Carefully dispose in a sanitary landfill.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
C6	Laminated bamboo *[Bamboo + resin + polyurethane adhesive]*	Roof structure, Woven wall panels, Partitioning, Formwork props, Scaffolding *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 21.7 - 24.0 CO_2 footprint (kg/kg): 1.63 - 1.80 Water usage (l/kg): 6.65 - 7.50	**Extraction** Refer to C4 **Production/Treatment/Toxicity** Refer to C5 No direct toxicity risk, unless the product contains formaldehyde resins or other hazardous chemicals (check product information) **Benefits** Refer to C5	Timber, Raw bamboo	Refer to C4	**Storage** Refer to C4 **Use** Refer to C1 **Disposal** Renewable resource, slow biodegradation. Combustion for energy should be done only after checking the material details and safety data sheets, otherwise landfill.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
D. Roofing Material						

D1	Asbestos (chrysotile) [Asbestiform varieties of mineral silicates belonging to the serpentine or amphibole groups of rock forming minerals. $Mg_3(Si_2O_5)(OH)_4$, Chrysotile accounts for 90% of the asbestos that is mined and used most commonly.]	Roofing sheets (mixed with cement), floor, thermal insulation, water pipes (mixed with cement), asbestos artex *[Banned in many countries due to its health hazards.* *Hazardous asbestos waste can be generated by a disaster and during search and rescue operations, clean-up operations, demolition, and transitional settlement and reconstruction activities.* *All forms of asbestos are considered to be carcinogenic by IARC. Chysotile is less carconogenic in comparison to other forms. Chrysotile has been investigated as a tumorigenic and mutagenic effector. It can enter the body through inhalation, ingestion, and skin. Fibers are loose and easily released into the air. Breathing these fibers can cause severe lung issues. Asbestosis is the most common disease caused by asbestos.*	**Extraction** Requires conventional mining practices to bring underground asbestos deposits and ore to the surface. **Production/Treatment** Involves complicated processes that include mining and separating. **Toxicity** Extremely hazardous to human health. **Benefits** None	PVA and cellulose fiber-cement, Polypropylene and cellulose fiber-cement, Bamboo fiber-cement (Taiheyo cement), Clay roofing tiles, Galvanized iron roofing (zinc-coated steel), Clay roof tiles, Thatching material, Aluminum sheets, Plastic roofing sheets, CGI sheets Alternatives to asbestos-cement pipes: Cast iron and ductile iron pipe; High-density polyethylene (HDPE); polyvinyl chloride (PVC) pipe, Pre-stressed (metal reinforced) concrete pipe; Clay pipe	• Do not recommend for any new construction • Do not recommend for any new construction • Identify the areas using it and assess the risks, ensure people are aware of the risks and handling practices • Minimize risk of using asbestos containing materials, and minimize human contact in all ways. Air-borne asbestos fibers are the main problem • Asbestos containing waste needs to be labeled properly and stored securely • In case of a disaster, trained personnel should handle the asbestos containing waste. Public awareness is important	**Storage** Do not receive, store, distribute, or dispatch asbestos products from any place of work unless they are suitably sealed and labeled. **Use** Strictly follow health and safety guidelines in removal. **Disposal** Strictly follow health and safety guidelines in removal and disposal, as it is an extremely hazardous material. Avoid recycle and reuse in any form. Minimize disturbance of asbestos containing materials Minimize interaction with asbestos containing materials Never burn, as that will release the fibers into the air The materials should be kept wet while disposal as that reduces the risk of airborne fibers Asbestos waste needs to be kept separate from other wastes and treated Break the cycle: avoid using new asbestos-containing materials in transitional settlement and reconstruction programs.
		Lung cancer and mesothelioma. Dangerous to use because of potential			•	

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
		degradation/damage which will release the fibers into the air. Respirable fiber level of 0.1 fibers/ml of air can be hazardous. Respirable asbestos means an asbestos fiber that is less than 3 micronmeters (μm) wide, more than 5 micronmeters (μm) long, and has a length to width ratio of more than 3:1.] **Embedded Energy/CO2 Footprint** Embodied energy (MJ/kg): 0.51 - 0.56 CO_2 footprint (kg/kg): 0.0268 - 0.0295 Water usage (l/kg): 37.7 - 41.7				

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
D2	Clay roof tiles *[63% Al_2O_3 (alumina), 36.7% SiO_2 (silica), <1% Fe_2O_3, K_2O, MgO]*	Roof sheltering *[provide high level of thermal comfort]* **Embedded Energy/CO2 Footprint** Embodied energy (MJ/kg): 13 - 14.4 CO_2 footprint (kg/kg): 1.82 - 2.01 Water usage (l/kg): 5.27 - 5.83	**Extraction** Requires clay, and clay mining causes habitat destruction, fouling of water bodies, and alters hydrology. **Transport** Transport of clay from pits can damage rural roads. **Production/Treatment** Manufacturing uses wood-fired kilns, but the process is more managed than brick-making. Kilns can cause severe air pollution due to improper quality control. **Toxicity** None **Benefits** None	Plastic/fiber glass roofing sheets, Thatching material	• Minimize use in areas with widespread clay mining impacts • Minimize roof area in design • Encourage reuse from old buildings • Procure proper estimates to minimize wastage	**Storage** Store in a dry place in suitable stack heights and use proper packaging and loading/ unloading in transport. **Use** Handle carefully. Broken tiles leads to wastage and may cause injuries. **Disposal** Refer to B1 Can be downcycled or landfilled. Not biodegradable, not recyclable, cannot be combusted for energy recovery.

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				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
D3	Corrugated Galvanized Iron (CGI) sheets *[Corrugated Iron sheets coated with zinc]*	Roof sheltering, Wall panels *[low thermal comfort, low durability in corrosive environments, use for wall panels suitable only in temporary installations]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 40.9 – 45.1 CO_2 footprint (kg/kg): 3.08 - 3.39 Water usage (l/kg): 56.30 - 62.20	**Extraction** Manufacturing process requires large quantities of steel, zinc, and other metals. May contribute to mining impacts. **Transport** Not significant **Production/Treatment** Manufacturing takes place in large-scale factories, using energy-intensive processes. Factories can cause severe air and water pollution if poorly managed. Manufacturing processes may release toxic heavy metals. **Toxicity** None **Benefits** None	Clay roof tiles, Aluminum sheets, Plastic/reinforced plastic roofing sheets, Thatching material	• Use optimum design calculations to minimize cut wastes • Use certified products and avoid using in corrosive environments • Avoid contact with ground or high levels of moisture if using for wall panels • Encourage reuse of un-corroded sheets from old buildings • Use standard sizes • If used for roofing, high noise will be produced during rainfall, and insulators will be needed • Avoid using in extreme temperatures, else use insulators along with it	**Storage** Store in a dry place in suitable stack heights and use proper packaging and loading/unloading procedures in transport. **Use** Not significant **Disposal** Never dispose of CGI in the environment; it can be easily sold as scrap metal.

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				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
D4	Thatching material *[Straw, coconut, reeds. Grasses. seaweed]*	Roof sheltering *[low durability, only usable in certain types of roof designs. If placed well, has high durability, is lightweight, and thus lesser amount of wood is needed to support it. Risk of fire, labor intensive, hence more expensive to thatch a roof than to cover it with tiles. Very common in UK.]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): straw: 0.24 CO_2 footprint (kg/kg): straw: 0.01 Water usage (l/kg): 670 - 730	**Extraction** Natural or farmed vegetation (e.g., palm leaves, reed, grasses) is used in harvesting. Without proper management, it may have impacts on forests and natural vegetation. **Transport** Not significant **Production/Treatment** Households or small-scale industries process material. Material needs seasoning and may cause water pollution if not properly managed. **Toxicity** None **Benefits** • No firewood or energy requirement • Can support indigenous livelihoods and knowledge • No requirement for quarried material or clay	Clay roof tiles	• Use local knowledge where possible • Use basic building designs • Use local knowledge where possible • Use basic building designs • Support local livelihoods and industries • Consider fire risk in planning and design since thatch is combustible	**Storage** Store in a dry place in suitable stack heights and order at correct time to avoid wastage. **Use** Use local thatching material that can be obtained without environmental damage. **Disposal** If thatching is not chemically treated, it is biodegradable. However, avoid disposing of large quantities in streams, estuaries and coastal areas. **Reuse** The type and quality of thatching material can vary. It is prone to decay in damp conditions and can be ruined by vermin. Thatched roofs are also very flammable. **Recycle** In decommissioning shelter/buildings, thatching can be composted or spread on the ground or ploughed into the soil and left to decompose naturally – provided it is not chemically treated.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
D5	AluminumAluminum sheets (3000 and 5000 series) *[Al+Mn,Mg, Cu, Si, Fe/Zn]*	Roof sheltering, Wall panels, Window and door frames *[use for wall panels suitable only in temporary installations* *Aluminum is lightweight but a strong metal which is not prone to corrosion, non-toxic, durable, and can be shaped as desired.* *Much more durable than CGI sheets, but more expensive.]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 200 - 221 CO_2 footprint (kg/kg): 12.5 - 13.8 Water usage (l/kg): 1140 - 1260	**Extraction** Manufacturing process requires large quantities of aluminum and other metals. May contribute to mining impacts. **Transport** Transport can damage rural roads. **Production/Treatment** Manufacturing takes place in large-scale factories using energy-intensive processes. Factories can cause severe air and water pollution if poorly managed. **Toxicity** None **Benefits** None	CGI sheets, Tin sheets, Plastic/fiber-reinforced plastic roofing sheets, Clay tiles, Thatching material	• Refer to D3 • Corrosion resistance makes aluminum sheets more environmentally appropriate in corrosive environments	**Storage** Refer to D3 **Use** Not significant **Disposal** Refer to D3 Can be easily recycled or downcycled, non-biodegradable. Aluminum is not a renewable resource. Non-reusable portion can be disposed in a landfill.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
D6	Fiber-reinforced plastic (FRP) *[PVC-80%, glass fiber (short fiber (<5mm))-20% (by weight)]*	Roof tiles, Window and door frames, Flooring, Wall panels *[use for wall panels suitable only in temporary installations]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 56.2 - 62 CO_2 footprint (kg/kg): 2.79 - 3.08 Water usage (l/kg): 214 - 236	**Extraction** None **Transport** Transport can damage rural roads. **Production/Treatment** Manufacturing takes place in medium-to large-scale factories using energy-intensive processes. Factories can cause severe air and water pollution if poorly managed. **Toxicity** No toxicity in use, but can emit hazardous fumes if burnt. **Benefits** Reduce environmental damage by using natural fibers and safe petroleum byproducts in manufacturing.	Plastic sheets, Thatching material	• Encourage the use of natural fibers (e.g., coir) in fiber reinforced plastic sheets • Design to optimum criteria to minimize wastage • Also refer to D3	**Storage** Store in proper sized stacks: raised from ground and in ways that would not sag. Can be combustible, store away from direct flames. **Use** Use protection when cutting the sheets as dust and fumes may cause health hazards. **Disposal** Never dispose of in the environment; only dispose of in a sanitary landfill. Never burn plastic sheets. High temperature incineration under expert supervision is possible as a last resort. Encourage reuse of material. Non-biodegradable, cannot be recycled. Can be put in landfill, combusted for energy, or downcycled.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
D7	Plastic sheets (Polyethylene) *[$(-CH_2-CH_2-)_n$]*	Roof sheltering, Wall panels *[use for wall panels suitable only in temporary installations]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 82.0 – 90.4 CO_2 footprint (kg/kg): 2.21 – 2.44 Water usage (l/kg): 61.2 – 68.4	**Extraction** Crude oil is the main raw material used for production. Large scale environmental issues are caused by the petroleum industry. **Transport** Not significant **Production/Treatment** Manufacturing takes place in medium- to large-scale factories using energy-intensive processes. Factories can cause severe air and water pollution if poorly managed. **Toxicity** No toxicity in use, but can emit hazardous fumes if burnt. **Benefits** None	Thatching material, Cement fiber sheets, Plywood	• Design to optimum criteria to minimize wastage • Use optimum design calculations to minimize cut wastes • Use certified products and avoid using in corrosive environments • Avoid exposure to direct sunlight where possible • Encourage reuse of undamaged sheets from old buildings	**Storage** Store in a covered place, away from direct sunlight or rain. Stack in an easily retrievable way to reduce tearing and damage. Highly combustible, store safe from all fire hazards. **Use** Use carefully to reduce damage and wastage. Don't expose to flames. Use personal protection when cutting large scale; dust and fumes may cause health hazards. **Disposal** Never dispose of in the environment; only dispose of in a sanitary landfill. Encourage reuse of material. Never burn plastic sheets. High temperature incineration under expert supervision is possible as a last resort. Polyethylene is easily recyclable if not coated with other materials Can be incinerated to recover energy

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
D8	Plastic sheets (PVC) *[Refer to C7]*	Roof sheltering, Wall panels *[use for wall panels suitable only in temporary installations]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 85.0 – 93.9 CO_2 footprint (kg/kg): 4.59 – 8.05 Water usage (l/kg): 197 - 218	**Extraction** Refer to D7 **Transport** Refer to D7 **Production/Treatment** Refer to D7 **Toxicity** Refer to D7 **Benefits** None	Thatching material, Cement fiber sheets, Plywood	Refer to D7	**Storage** Refer to D3 **Use** Refer to D6 **Disposal** Refer to D7

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
D9	Galvanized steel *[Fe (base material), Mn, C, Si, P, coated with Zn]*	Roofing, Wall panels *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 38.1 - 42.0 CO_2 footprint (kg/kg): 2.87 - 3.16 Water usage (l/kg): 56.3 - 62.2	**Extraction** Refer to D3 **Transport** Refer to D3 **Production/Treatment** Refer to D3 **Toxicity** None **Benefits** None	Aluminum sheets, tin sheets	Refer to D3	**Storage** Store in a dry place in suitable stack heights and use proper packaging and loading/unloading procedures in transport. **Use** Not significant **Disposal** Never dispose in the environment; it can be easily sold as scrap metal.
D10	Stone (slate) *[63% CaO, 21% SiO_2, 6% Al_2O_3 + additions]*	Roofing (slate tiles) **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 11.0 - 12.2 CO_2 footprint (kg/kg): 0.81 - 0.09 Water usage (l/kg): 3.23 - 3.57	**Extraction** Refer to A3 **Transport** Refer to A3 **Production/Treatment** Refer to A3 **Toxicity** None **Benefits** None	Clay tiles, Reinforced cement sheets, Reinforced plastic sheets, Corrugated Galvanized Iron sheets	Refer A3	**Storage** Refer to A1 **Use** Refer to A1 **Disposal** Refer to A1

E. Finishing Materials

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
E1	Ceramic tiles *[63% Alumina, 37% Silica, <1% of ferric oxide, potassium oxide, magnesia]*	Floor tiling, Wall tiling *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 14.6 - 15.1 CO_2 footprint (kg/kg): 1.84 - 2.10 Water usage (l/kg): 12.0 - 13.2	**Extraction** Requires clay, and clay mining causes habitat destruction, pollutes water bodies, alters hydrology. **Transport** Transport can damage rural roads. **Production/Treatment** Manufacturing takes place in large industrial kilns. It is highly energy intensive, and if not properly managed, factories can cause air and water pollution. **Toxicity** Glazing may use toxic compounds. **Benefits** None	Terracotta tiles, Cement tiles, Vinyl tiles, Polymer composite tiles	• Use optimal design (use only where necessary, limit aesthetic use) • Use standard sizes and shapes to minimize cut-offs	**Storage** Requires proper transport and handling. Store in safe, dry place in proper stack heights. **Use** Use protection when cutting. **Disposal** Refer to B1 Non-biodegradable, downcycle, landfill. Reuse if in undamaged condition. **Recycle:** Recovered tiles can be crushed and used as aggregate, landscaping, or infill purposes.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
E2	Parquet *[Timber]*	Floor paving *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 45.8 - 107 CO_2 footprint (kg/kg): 4.4 - 7.1 Water usage (l/kg):	**Extraction** Manufacturing uses timber. (see C1) **Transport** See C1 **Production/Treatment** See C1 **Toxicity** See C1 **Benefits** None	Ceramic tiles, Terracotta tiles, Cement tiles, Vinyl tiles, Polymer composite tiles	• Limit foot traffic on finished wood flooring • Complete wood flooring toward the end of the construction project • Use optimal design (use only where necessary, limit aesthetic use) • Use standard sizes and shapes to minimize trimmings and cut-offs	Refer to C1 and C3

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
E3	Lime mortar/ Lime putty *[Lime, water, sand (fine aggregate)]*	Plastering Filler, Paint *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 732 CO_2 footprint (kg/kg): 0.15 - 0.23 Water usage (l/kg):	**Extraction** Manufacturing uses limestone or coral. Coral extraction causes serious environmental damage. Mining small outcrops of limestone may also have significant environmental impacts. **Transport** Transport can damage rural roads. **Production/Treatment** Requires kilning to produce usable non-hydraulic or hydraulic lime. The kilning process (especially small-scale) causes air pollution. **Toxicity** None **Benefits** None	Cement mortar, Chemical fillers	• Do not use lime made from coral or illegally mined limestone • Minimize the use of lime from small-scale producers with wood-fired kilns • Mix only required amounts to minimize waste • Use prefabricated concrete items and standard sized bricks or blocks to minimise the lime mortar and plaster requirement	Refer to A4

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
E4	Chemical fillers *[pulverized glass, limestone powder, recycled plastics/ rubbers]*	Filler *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): CO_2 footprint (kg/kg): Water usage (l/kg):	**Extraction** Requires mined and quarried material. See A3 **Transport** See A3 **Production/Treatment** Manufacturing takes place in large-scale factories and can cause air and water pollution if not properly managed. **Toxicity** Production may use toxic compounds that can cause environmental and health hazards. **Benefits** Reduce the demand for lime produced in harmful small-scale industries	None	• Refer to the Material Safety Data Sheets before design or purchase • Avoid toxic fillers unless absolutely necessary and educate the craftsperson about safe use and disposal • Do not over-specify	**Storage** Store the properly closed containers (airtight) in safe places. **Use** Finish the walls smoothly before application and apply in optimum thicknesses (do not over-specify). Mix only required amounts to minimize waste. Strictly follow Health and Safety guidelines when working with chemical fillers. **Disposal** Never dispose of hardened filler or their containers in the environment. Instead, dispose of them in a sanitary or hazardous waste disposal facility (for toxic fillers).

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
E5	General emulsion or latex paint *[water-borne dispersion of sub-micrometer polymer particles]*	Painting *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 68.0 CO_2 footprint (kg/kg): 3.56	**Extraction** Requires a variety of base chemicals in addition to mined and quarried material. **Transport** Transport can damage rural roads. **Production/Treatment** Manufacturing takes place in large-scale factories and can cause air and water pollution if not properly managed. **Toxicity** Enamel paint uses solvents. Some solvents may be harmful to human health and the environment. **Benefits** None	Natural pigments	• Refer to the Material Safety Data Sheets before design or purchase • Avoid toxic paints unless necessary, and educate the craftsperson about safe use and disposal • Specify only the required number of coats of paint • Limit the use of solvents and educate the craftsperson about safe use and disposal of solvents	**Storage** Store the properly closed containers (airtight) in safe places. **Use** Use protection when mixing and applying paints. **Disposal** Never dispose of hardened fillers or their containers in the environment; instead dispose of them in a sanitary or hazardous waste disposal facility (for toxic paints or solvents).

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
E6	Epoxy paints/oil-based enamel paints/solvent-based paints/strong adhesives/paint remover	Painting, Metal protection (as adhesives) *[generally expensive and used only for specific purposes]*	**Extraction** Requires a variety of base chemicals in addition to mined and quarried material. **Transport** Transport can damage rural roads. **Production/Treatment** Manufacturing takes place in large-scale factories that can cause air and water pollution if not properly managed. Production processes of some of these chemicals may be extremely damaging to the environment and human health. **Toxicity** May release heavy metals and harmful organic compounds into the environment. **Benefits** None	None	• Use certified products only • Use only where it is absolutely necessary and avoid if possible • Specify only if essential for the strength or durability of the building—not for ease of construction • Refer to E5	**Storage** Store the properly closed containers (airtight), in a safe, secured place—away from fire and flooding hazards. **Use** Should be handled only by trained crafts persons, using protective equipment and strictly following Health and Safety Executive (HSE) guidelines in mixing and use. **Disposal** Treat strictly as hazardous waste in disposal of excess material and containers.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
E7	Termite treatment chemicals	Chemical treatment to eradicate termites (applied to soil around the perimeter and the subfloor of a building)	**Extraction** Requires a variety of chemicals. **Transport** Transport can damage rural roads. **Production/Treatment** Large-scale factories produce. **Toxicity** Production process may release heavy metals and toxic organic compounds into the environment. Industrial accidents may cause serious hazards to humans and the environment. **Benefits** None	Use of ground electrocution Integrated pest management	• Only use certified products • Try to use integrated pest management methods to get rid of pests	**Storage** Store the properly closed chemical containers (airtight), in a safe, secured place—away from fire and flooding hazards. **Use** Only use in specified dosages and with trained and certified persons. Use protective equipment and strictly follow Health and Safety guidelines in mixing and use. **Disposal** Treat strictly as hazardous waste in disposal of excess material and containers.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
E8	Glass *[73% SiO_2, Al_2O_3, Na_2O, MgO, CaO]*	Window panes *[Glass is a fully recyclable material and is chemically inert]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 17.8 – 20.6 CO_2 footprint (kg/kg): 1.35 – 1.56 Water usage (l/kg): 1.54 (Dai, 2015)	**Extraction** Requires quarried and mined material in production. **Transport** Transport can damage rural roads. **Production/Treatment** Results in mass combustion of fossil fuel. Emits sulphur dioxide (SO_2), and if unmanaged, it may cause water pollution. **Toxicity** None **Benefits** None	Plastic polycarbonate	• Use standard sizes and minimize trimming • Use only the required thickness; however, thin plate glass is susceptible to easy breaking and waste of material	**Storage** Transport, handle, and store with care in proper stack height to avoid breakage and waste. Glass can be hazardous to children. **Use** Handle carefully, using proper equipment; broken glass can cause serious injury. **Disposal** Glass can be easily sold for recycling, and it should never be disposed of in the environment. Recycle, downcycle, landfill. Non-renewable, non-biodegradable, not combusted for energy recovery.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
E9	Tarpaulin sheets *[polyester]*	Shelter material and wall panels (in temporary structures), Weather proofing building sites *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 82.5 – 92.7 CO_2 footprint (kg/kg): 4.387 - 5.225 Water usage (l/kg):	**Extraction** Tarpaulin sheets are layered sheets that sandwich a polyester woven fabric base between plastic films. Refer to D7 **Transport** Refer to D7 **Production/Treatment** Refer to D7 **Toxicity** Refer to D7 **Benefits** None	Waterproof canvas, Thatching material	Refer to D7 (Tarpaulin sheets have a higher durability in outdoor uses than single film plastic sheets)	Refer to D7
	F. Insulation Material					

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
F1	Polystyrene foam/ expanded polystyrene *[Polystyrene foam closed cell (0.025 specific gravity)]*	Insulation *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 116 - 128 CO_2 footprint (kg/kg): 5.61 - 6.20 Water usage (l/kg): 433 - 479	**Extraction** Polystyrene foam is made out of the common plastic polystyrene. Refer to D7 **Transport** Refer to D7 **Production/Treatment** Refer to D7 **Toxicity** Refer to D7 **Benefits** None	Natural fiber insulation, glass, or rock wool	• Non-biodegradable, hence plan how much amount is needed and don't overuse • Avoid using poor quality products	Refer to D7

F2	Gypsum board *[calcium sulfate dihydrate (gypsum) with or without additives and normally pressed between a facer and a backer]*	Wall partition, Fire protection, Repair and finishing material *[Easier to install and cheaper than plaster]* **Embedded Energy/CO2 Footprint** Embodied energy (MJ/kg): 10.4 – 11.6 CO_2 footprint (kg/kg): 0.88 - 0.98 Water usage (l/kg): 665 - 735	**Extraction** Extraction can cause forest destruction, landslides, land degradation, and habitat destruction and can increase flood risk. **Transport** Transport can damage rural roads. **Production/Treatment** Processing takes place in timber mills. Mills that are poorly managed cause solid-waste pollution, and noise and air pollution. **Toxicity** Requires treatment for pest control. Using toxic chemicals for treatment causes environmental and health hazards. **Benefits** None	Cement plaster, plasterboard	• Use standard sizes • Can even be installed by amateur carpenters • Much faster process than plastering walls	**Storage** Refer to C3 **Use** Refer to C3 Cutting or breaking of gypsum board release fine particulate matter. Cutting or breaking should be minimised and done off-site if possible. **Disposal** Plasterboard is likely to be damaged during a disaster and therefore unsuitable for reuse. Can be disposed in an engineered landfill. **Recycle:** Gypsum makes up approximately 90% of the weight of a piece of plasterboard. Gypsum can be recovered and used : • in the manufacture of new drywall • as an ingredient in the production of cement • for application to soils and crops to improve soil drainage and plant growth • an ingredient in the production of fertilizer products • an additive to composting operations. However, this is unlikely in most emergency responses

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
F3	Low strength glass fiber *[59.5% SiO_2, 5% Al_2O_3, 7% B_2O_3, 14.5% Na_2O, 8% TiO_2, 4% ZrO_2]*	Insulation fiber *[The legal permissible exposure limit has been set to 15 mg/m3 and 5 mg/m3 in respiratory exposure over an 8 hour workday by occupational Safety and Health Administration (OSHA)]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 25.7 - 28.3 CO_2 footprint (kg/kg): 0.831 - 0.917 Water usage (l/kg): 43.7 - 48.3	**Extraction** Manufactured using glass. Refer to E8 **Transport** Refer to E8 **Production/Treatment** Refer to E8 **Toxicity** Refer to E8 **Benefits** None	Polystyrene foam, Natural fiber insulation, Rock wool	• Safety practices are required. The Materials Safety Data Sheet (MSDS) should be consulted	**Use** Should never be left exposed in an occupied area. Avoid unnecessary contact with dusts and fibers by using Personal Protection and good local exhaust ventilation. **Disposal** Landfill, downcycle, non-biodegradable. Cannot be recycled. Cannot be combusted for energy.

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
F4	Fiberboard *[Different from plywood as that is made from sheets of wood, while this is made from fibers. Cellulose/hemicellulose/lignin/ 12% water/ adhesive]*	Insulating formboard, Roof insulating board, Sound insulation *[Refer to C3]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 10.9 - 11.9 CO_2 footprint (kg/kg): 0.39 - 0.41 Water usage (l/kg): 665 - 735	**Extraction** Manufactured using cellulose/hemicellulos fibers. Refer to C3 **Transport** Refer to C3 **Production/Treatment** Refer to C3 **Toxicity** Refer to C3 **Benefits** None	Engineered bamboo (Woven bamboo panels, bamboo scrimber, laminated bamboo), thatching material	Refer to C3	Refer to C3

G. Special Materials

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
G1	Polyurethane foam *[Polyurethane closed cell flexible foam]*	Sealants, Concrete jointing, Foundation repair, Insulation *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 117 - 130 CO_2 footprint (kg/kg): 7.52 – 8.30 Water usage (l/kg): 280 - 310	**Extraction** Foam is made of the hydro-carbon polymer type Polyurethane. Refer to D7 **Transport** Refer to D7 **Production/Treatment** Refer to D7 **Toxicity** Refer to D7 **Benefits** None	Natural fiber insulation, glass or rock wool for insulation applications. Polystyrene foam in sealing and joining applications.	• Non-biodegradable, hence plan how much amount is needed and don't overuse • Avoid using poor quality products	Refer to D7

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
G2	Polypropylene *[$(C_3H_6)_n$]*	Sound insulation, Wall insulation, Water pipes, Waste pipes, Can also be used to reinforce concrete *[None]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 114 - 126 CO_2 footprint (kg/kg): 5.82 – 6.39 Water usage (l/kg): 37.2 - 41.2	**Extraction** Made of hydro-carbon polymer type Polypropylene. Refer to D7 **Transport** Refer to D7 **Production/Treatment** Refer to D7 **Toxicity** Refer to D7 **Benefits** None	Polyuerethane foam, Natural fiber insulation, Glass or rock wool for insulation applications. PVC or High Density Polyethylene (HDPE) for pipes	• Non-biodegradable, hence plan how much amount is needed and don't overuse • Avoid using poor quality products	Refer to D7
G3	High strength glass fiber *[E grade fiber (0.4-12 micron filament) 54% SiO_2, 15% Al_2O_3, 12%CaO]*	Reinforcement *[Refer to F3]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 89.9 – 99.0 CO_2 footprint (kg/kg): 6.10 – 6.72 Water usage (l/kg): 89.8 - 99.2	**Extraction** Manufactured using glass. Refer to F3 **Production/Treatment** Refer to F3 **Toxicity** Refer to F3 **Benefits** None	PVA and cellulose fiber-cement, Polypropylene and cellulose fiber-cement, Bamboo fiber-cement (Taiheyo cement), Clay roofing tiles, Galvanized iron roofing (zinc-coated steel),	Refer to F3	Refer to F3

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
G4	Natural Rubber *[latex of the rubber tree]*	Anti-vibration pads, Window seals, Sound insulation, Flooring *[Easy to handle and install, good energy storage capacity]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 85.8 – 94.9 CO_2 footprint (kg/kg): 3.67 – 4.05 Water usage (l/kg): 15000 - 20000	**Extraction** Rubber is manufactured using latex of the rubber tree. A renewable resource. However, rubber plantations are monoculture and can cause long term ecological degradation, if managed without responsible plantation practices. **Transport** Not significant **Production/Treatment** Rubber production is a large scale process involving many hazardous chemicals, such as ammonia. Can cause air and water pollution if not properly managed. **Toxicity** Not significant **Benefits** None		• Use certified products as standards and quality varies with location • Where possible sustainably sources and environmentally certified rubber. There are many certification programs available. • Consider vibration control strategies early in the product design process and consulting with an engineering expert when selecting materials and mounts • Optimize the use of material to reduce wastage	**Storage** Always store rubber products away from direct flames and other fire hazards. Store in place above ground, away from excessive moisture and direct sunlight. Store in way that is easy retrievable to avoid damage. **Disposal** Refer to F3

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
G5	Neoprene Rubber *[Polychloroprene]*	Seals, Adhesives *[higher resistance to heat but lower resistance low-temperature stiffening compared to natural rubber]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 81.9 – 90.0 CO_2 footprint (kg/kg): 2.25 - .2.58 Water usage (l/kg): 126 - 378	**Extraction** Manufactured by polymerisation of the clorianted hydro-carbon chloroprene. Refer to D7 **Transport** Refer to D7 **Production/Treatment** Refer to D7 **Toxicity** Some incidents of skin irritations and allergy reported due to residues of Ethylene Thiourea. **Benefits** None	Natural rubber, Butyl rubber, Polyisoprene	• Non-biodegradable, hence plan how much amount is needed and don't overuse • Avoid using poor quality products	Refer to D7

Item No.	Material *[composition]*	Technical Information *[special technical remarks]*	Environmental Costs / Impacts / Benefits	Management & Alternatives		
				Potential Material Alternatives	Environmental Better Practices (Design/Planning)	Environmental Better Practices (Storage/Use/Disposal)
G6	Styrene Butadiene Rubber (SBR) *[23% styrene and 77% butadiene reinforced with typically 30% carbon black]*	Anti-vibration pads, Window seals, Sound insulation, Flooring *[weaker and lower fatigue resistance compared to natural rubber]* **Embedded Energy/CO_2 Footprint** Embodied energy (MJ/kg): 129 - 143 CO_2 footprint (kg/kg): 7.64 – 8.45 Water usage (l/kg): 63.7 - 191	**Extraction** Manufactured using hydro-carbons Styrene and Butadiene. Refer to D7 **Transport** Refer to D7 **Production/Treatment** Refer to D7 **Toxicity** Some incidents of skin irritations and allergy reported due to residues of Ethylene Thiourea. **Benefits** None	Natural rubber, Neoprene rubber, Polyisoprene	• Non-biodegradable, hence plan how much amount is needed and don't overuse. • Avoid using poor quality products	Refer to D7

Table 2: ENVIRONMENTAL GUIDE TO PROPERTIES OF COMMON BUILDING MATERIALS

No.	Material *[composition]*	MECHANICAL PROPERTIES						THERMAL PROPERTIES			Electrical resistivity (μΩcm)	DURABILITY					
		Density (kg/m3)	Young's modulus (GPa)	Tensile strength (MPa)	Compressive strength (MPa)	Flexural strength (MPa)	Shape factor	Max service temp (ºC)	Min service temp (ºC)	Thermal conductivity (W/m.ºC)		Water (fresh)	Water (salt)	UV radia-tion	Flammability	Insects, mold, and termite	Comments
												1 = Poor 2 = Limited 3=Acceptable 4 = Good 5 = Excellent			1 = High 2 = Flammable 3 = Slow 4 = Self extinguishing 5=None	1 = Susceptible to attack 3 = Good 5 = Excellent	
A1	River sand	2600	0.01-0.69	2.2-3.75	38-46	3.09-3.98	-	-	-	1.5-1.8	-	5	5	5	5	3	
A2	River gravel/ boulders	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	
A3	Quarried rock	2550-2600	35-55	8-22	30-200	8-22	15	330-380	-	0.92-2.15	1e8-1e12	5	5	5	5	3	
A4	Portland Cement	1800-2200	30.2-41.6	1.9-3	24-27	2.2 - 2.5	3	627-857	-160- -150	0.8-0.9	2e11-2e12	5	5	5	4 (until 450 ºC)	3	Poor with sulfates and not acceptable with sulfuric acid
A5	Stone (sandstone)	2000-2600	14-25	4-22	50-155	4 - 22	15	400-600	-273	5.4 - 6	1e10 - 1e14	5	5	5	5	3	Excellent durability in acidic and alkaline soils
A6	Concrete (not reinforced)	2300-2600	16-25	1-1.5	14-50	1.7 - 2.4	3	480-510	-163- -153	0.8-2.4	1.85e12-1.85e13	5	5	5	5	3	Excellent durability with soils, poor with sulfates, SO_2 and not acceptable with sulfuric acid
A7	Concrete (insulating, lightweight)	900-1400	0.6-1.53	0.1-0.3	0.5-8.2	0.3-5	3	560-640	-160	7-12	3.16e11-3.16e12	5	3	5	5	3	Limited use with acids and alkalis

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		Density (kg/m3)	Young's modulus (GPa)	Tensile strength (MPa)	Compressive strength (MPa)	Flexural strength (MPa)	Shape factor	Max service temp (ºC)	Min service temp (ºC)	Thermal conductivity (W/m.ºC)		Water (fresh)	Water (salt)	UV radia-tion	Flammability	Insects, mold, and termite	Comments
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A8	Aerated concrete (low density)	400-900	12-18	0.6-1.1	1.2-1.87	0.7-1.3	3	200-300 (decrease from normal concrete due to air gaps)	-160 - -150	0.7-0.8	3.16e11-3.6e12	5	3	5	5	3	Excellent with soils, poor with sulfates, not acceptable with sulfuric acid
A9	High volume fly ash concrete	1830-2200	30-41	1.5-2.5	45-58	1.5-2.5	3	873-973	-	1.11-125	2e11-2e12	5	3	5	5	3	Excellent with soils, poor with sulfates, unacceptable with strong acids
A10	Latex concrete	2300-2600	20.39-34.56	3-5	21-38	3-6.5	-	480-510	-163- -153	0.8-2.4	1.85e12-1.85e13	5	5	5	5	3	

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A11	PVA and cellulose fiber-cement	1610-1870	0.25-3.90	34.1-84.9		19.2	-	226-240				4			4	3	High alkaline environments can cause degradation of natural fibers (Pacheco-Torgal, 2011)
A12	Polypropylene fiber-reinforced concrete	360-567	12.8±2.3	1.08-5.40	12.6-81.6	2.50-6.84	-	300-600				3	3		5	3	
A13	Cellulose fiber-reinforced concrete	2050-2250	13.3±1.2	2.69-3.41	35.8-38.7	5.46-6.35	-			1.8-2.7		3	3				

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A14	Glass Fiber reinforced composite (GFRP) rebar	1750-1900	15-28	138-241	138-207	-	-	140-220	-73.2	0.4-0.55	2.4e21-1.91e22	5	5	3	3		Limited use in acidic (peat) and alkaline soils (clay)
A15	Low carbon steel	7800-7900	200-215	345-580	250-395	1.52e3 - 1.68e3	14	350-400	-68.2- -38.2	49-54	15-20	3	2	5	5	5	Better durability with alkaline that acidic environment
B1	Brick (common)	1600-2100	15-30	5-14	10-70	-	15	927-1230	-	0.46-0.73	1e14-3e16	5	5	5	5		
B2	Cement blocks	1800-2200	30.2-41.6	1.9-3	24-27	2.2 - 2.5	3	627-857	-160- -150	0.8-0.9	2e11-2e12	5	5	5	4 (until 450 ºC)		Poor with sulfates and not acceptable with sulfuric acid

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B3	Compressed stabilized earth blocks/ CSEB	1900-2200	0.7-1	1-2	2-3	1-2	-			0.46-0.81		2			4		5-10 wt% absorption of water durability against water increases with cement content
B4	Earth walls (stabilized earth, clay-straw, rammed earth, bamboo reinforced earth)	1800-2000	2.51	0.13-0.27	1.38 - 3.09	0.30 - 0.92				1.51		3			4		Proper soil selection is necessary to maintain durability during heavy rainfalls
C1	Forest timber	850-1030	20.6-25.2	132-162	68-83	114 - 140	5.1 - 5.7	120-140	-100--70	0.41-0.5	6e13-2e14	3	3	4	1	1	Acceptable in acidic soils (peat)/ limited use in alkaline soils (clay)
C2	Farmed timber	850-1030	20.6-25.2	132-162	68-83	114 – 140	5.1 - 5.7	120-140	-100--70	0.41-0.5	6e13-2e14	3	3	4	1	1	Acceptable in acidic soils (peat)/ limited use in alkaline soils (clay)

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C3	Plywood/ laminated panels, Chip boards, Fiber boards	700-800	6.9-13	10-44	8-25	80-115	5	100-130	-100--70	0.3 - 0.5	6e13-2e14	3	3	4	1	1	Limited used in acidic soils (peat)/ unacceptable in alkaline soils (clay)
C4	Bamboo	600-800	15-20	160-320	60-100	80-160	5.6	120-140	-73--23	0.16-0.18	6e13-2e14	2	2	4	1	1 (treating or coating can help)	Unacceptable with strong acids and alkalis, limited use with weak acids and alkalis
C5	Bamboo scrimber	1160	0.05-0.06	120	86	119	-	120	-	0.1625	6e13-2e14	4	4	4	2	3	-
C6	Laminated bamboo	686	11-13	90	77	77-83	-	120	-	0.186	6e13-2e14	4	4	4	2	3	-

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C7	Hardwood (oak)	850-1030	20.6-25.2	132-162	68-83	114 – 140	5.1 - 5.7	120-140	-100--70	0.41-0.5	6e13-2e14	3	3	4	1	1	Acceptable in acidic soils (peat)/limited use in alkaline soils (clay)
D1	Asbestos (chrysotile)	2400 – 2600	161 - 169	2.95e3 - 3.35e3	-	-	1	852 - 980	-273	2 - 6	1e22 - 1e24	5	5	5	5	-	2400 - 2600
D2	Clay roof tiles	1.9e3 - 2.75e3	4 - 8	15 - 20	25 - 28	16.6 - 29.5	13	673 - 773	-	0.5 - 1.52	-	3	5	5	5	-	-
D3	Corrugated Galvanized Iron (CGI) sheets	78e3-7.9e3	200-215	420-600	250-395	250-395	60	150-180	-68.2--43.2	50-54	15-20	5	3	5	5		Limited use with acids and alkalis. Galling resistance is poor. Zinc coating has tendency to gall.
D4	Thatching material	-	-	-	-	-	-			reed: 0.11 date palm leaves: 0.122-0.210						1	Reed in Europe, Cadjan (Palm/Coconut leaf) in South India/SE Asia, Straw in North India/Middle East
D5	Aluminum sheets (3000 and 5000 series)	2500-2900	68-72	70-360	30-286	59 – 105	42	130-220	-273	119-240	2.5-6	5	3	5	5		Unacceptable with acidic soils (peat)

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D6	Fiber-reinforced plastic (FRP)	1750-1900	15-28	138-241	138-207	-	-	140-220	-73.2	0.4-0.55	2.4e21-1.91e22	5	5	3	3		Limited use in acidic (peat) and alkaline soils (clay)
D7	Plastic sheets (Polyethylene)	939 – 960	0.621 - 0.896	20.7 - 44.8	19.7 - 31.9	18.6 – 37	3.5	90 - 110	-123 - -73.2	0.403 - 0.435	3.3e22 - 3e24	5	5	2	1	PVC: 3	Treat with fire retardant
D8	Plastic sheets (PVC)	1303 – 1580	2.14 - 4.14	40.7 - 65.1	42.5 - 89.6	82 – 90	5.3	60 - 70	-123 - -73.2	0.147 - 0.293	1e20 - 1e22	5	5	4	4		-
D9	Galvanized steel	7800-7900	200-215	420-600	250-395	250-395	60	150-180	-68.2- -43.2	50-54	15-20	5	3	5	5		Limited use with acids and alkalis. galling resistance is poor. Zinc coating has tendency to gall.
D10	Stone (slate)	2600-2800	60-90	15-30	120-175	15-175	15	350-500	-50 - -30	1.2-2.1	1e12-1e14	5	3	5	5	3	
E1	Ceramic tiles	2050-2400	4-8	3-6	20-50	3-6	15	673-1070	-	0.75-0.85	1e14-3e14	5	5	5	5	3	Unacceptable with alkalis

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E6	Epoxy paints/ solvent based paints/anticorrosive paints/strong adhesives/paint remover	1110 – 1400	2.35 - 3.08	45 - 89.6	39.6 - 78.8	-	-	140 - 180	-123 - -73.2	0.18 - 0.5	1e20 - 6e21	5	5	3	3		
E8	Glass	2440-2490	68-72	31-35	360-420	40 – 45	15	170-400	-	0.7-1.3	7.9e17-7.9e18	5	5	5	5		
E9	Tarpaulin sheets	1450 – 1550	61.4 - 128	400 - 938	-	-	1	400 - 420	-	0.25 - 0.35		5	5	4	1		
F1	Polystyrene foam/ expanded polystyrene	75-85	3.3e-4 - 4e-4	0.125-0.15	0.023-0.03	0.025-0.03	1.9	72-77	-53 - -23	0.024-0.028	1e18-1e19	5	3	3	3		Unacceptable with strong acids and alkalis
F2	Gypsum board	623-770	1.7 - 2.5	1.0 - 2.0	2.40-2.75	2.25-3.79		320		0.125 - 0.50							623-770
F3	Low strength glass fiber	2540-2590	57.8-76.7	25.6-34.4	256-344	57.8-76.7	1	157-426	-	0.9-1.2	1e22-1e24	5	2	5	5	-	2.54e3-2.59e3
F4	Fiberboard	160-480	0.3-0.9	1.8-4.2	0.05-0.1	1.8-8.3	5.6	120-140	-73 - -23	0.3-0.35	3e12-7e14	2	2	4	1	1	160-480

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G1	Polyurethane foam	75-85	3.3e-4 - 4e-4	0.125-0.15	0.023-0.03	0.025-0.03	1.9	72-77	-53 - -23	0.024-0.028	1e18-1e19	5	3	3	3		Unacceptable with strong acids and alkalis
G2	Polypropylene	36-70	0.023-0.08	0.45-2.25	0.37-1.7	-	-	100-115	-113 - -73.2	0.023-0.04	1e17-1e21	5	5	4	4		Excellent with acidic and alkaline soils
G3	High strength glass fiber	2550-2600	72-85	1.95e3-2.03e3	4e3-5e3	3300-3450	1	350-360	-	1.2-1.35	1e22-1e23	5	5	5	5	-	
G4	Natural Rubber	920-930	0.0015 - 0.0025	22-32	22-33	36.8 - 47.2	1.5	68.9-107	-56.2 – -43.2	0.1-0.14	1e15-1e16	5	5	1	1		
G5	Neoprene Rubber	1239 – 1300	0.00165 - 0.0021	12 - 24	14.4 - 28.8	0.00165 - 0.0021	1.5	102 - 112	-55 - -40	0.15 - 0.2	1e17 - 1e19	5	5	1	4		
G6	Styrene Butadiene Rubber (SBR)	940 – 961	0.002 - 0.01	1.4 - 3	0.002 - 0.01	7.73 - 10.1	1.7	70 - 110	-50 - -40	0.19 - 0.25	5.01e21 - 7.94e21	5	5	1	1		

ADDITIONAL RESOURCES

1. Inter-Agency Standing Committee (IASC). 2010. *Debris as a Construction Material: The Environmental and Economic Benefits*. https://www.sheltercluster.org/sites/default/files/docs/Debris%20reuse%20for%20Construction.pdf

2. United Nations Development Programme (UNDP). 2013. *Debris Management: The Door to Development*. http://www.ht.undp.org/content/dam/haiti/docs/reduction%20de%20la%20pauvrete/Debris%20-TOI%20EN%20Final%2020130718.pdf

3. United Nations Environment Programme (UNEP). 2008. *After the Tsunami: Sustainable building guidelines for South-East Asia*. http://www.unep.org/sbci/pdfs/After-Tsunami-Sustainable-building-guidelines.pdf

4. UNDP. *Environmental Procurement Practice Guide.* http://www.ht.undp.org/content/dam/haiti/docs/reduction%20de%20la%20pauvrete/Debris%20-TOI%20EN%20Final%2020130718.pdf

5. WWF-Nepal. *Beyond Investment: Developing sustainable green infrastructure in Nepal*. Hariyo Ban Program, WWF Nepal, Kathmandu, Nepal. http://d2ouvy59p0dg6k.cloudfront.net/downloads/beyond_investment.pdf

6. WWF-US and American Red Cross. 2010. *Module 5: Materials and the Supply Chain, Green Recovery & Reconstruction: Training Toolkit for Humanitarian Aid* (GRRT). http://envirodm.org/training/eng/green-guide-to-materials-and-the-supply-chain

Prefabricated timber frames stacked for construction of intermediate shelters. 2010 earthquake reconstruction in Port-Au-Prince, Haiti.

BIBLIOGRAPHY

1. "Al-Juruf, R. S., Ahmed, F. A., Alam, I. A., & Abdel-Rahman, H. H. (1988). Determination of the Thermal Conductivity of Date Palm Leaves. Journal of Thermal Insulation, 11.
2. Akers, S.A.S., Studinka, J.B., Meier, P., Dobb, M.G., Johnson, D.J., & Hikasa, J. (1989). Long term durability of PVA reinforcing fibers in a cement matrix. International Journal of Cement Composites and Lightweight Concrete, 11(2), 79-91. https://doi.org/10.1016/0262-5075(89)90118-8
3. Aluminum Association. “Guidelines for in-plant handling of aluminum plate, flat sheet and coil.” Arlington, VA: The Aluminum Association, 2006. Accessed September 15, 2016. http://www.aluminum.org/sites/default/files/Guidelines_for_in_plant_handling_of_aluminum_plate_flat_sheet_and_coil.pdf
4. Ambuja Foundations. “Environment Impact.” Accessed September 15, 2016. http://foundationsakc.com/process/environment-impact
5. Annex: Corrugated Galvanised Iron (CGI) Specifications for Roofing. Kathmandu: Shelter Cluster Nepal. https://www.sheltercluster.org/sites/default/files/docs/cgi_specification_150708.pdf
6. AnyWay Solid Environmental Solutions Ltd. “Introduction to the Production of Compressed Stabilized Earth Block (CSEB).” AnyWay Solid Environmental Solutions, 2014. Accessed September 15, 2016. http://www.anywaysolutions.com/wp-content/uploads/2010/08/introduction-to-the-production-of-CSEB-using-AnyWay-Soil-Block-last-updated-20121.pdf
7. Arbeitsgemeinschaft der Schweizerischen PVC Industrie (PVCH), PVCplus Kommunikations GmbH. Everything About PVC From Manufacturing To Recycling. Germany: PVCplus Kommunikations GmbH, 2012.
8. Asociación Nacional de Fabricantes de Cales y Derivados de España (ANCADE) [Spanish National Association of Manufacturers of Lime and Lime Derivatives]. “Practical Guide to Lime Mortars.” Accessed September 15, 2016. www.eula.eu/file/464/download?token=3WJ3Odj1
9. Auroville Earth Institute (AVEI). “Compressed Stabilized Earth Blocks.” AVEI, 2013. Accessed September 15, 2016. http://www.earth-auroville.com/maintenance/uploaded_pics/cseb.pdf
10. Bamboo-reinforced Masonry In Earthquake-prone Areas In India. https://arch.usc.edu/sites/default/files/mbs/.../shreemathi%20iyer.pdf

11. Behnood, A. and Ghandehari, M. (2009). Comparison of compressive and splitting tensile strength of high-strength concrete with and without polypropylene fibers heated to high temperatures. Fire Safety Journal, 44(8), 1015.1022.
12. Bei-xing, L., C. Ming-xiang, C. Fang, and L. Lu-ping. 2004. The mechanical properties of polypropylene fiber reinforced concrete. Journal of Wuhan University of Technology: Material Science Edition 19(3): 68-71.
13. Bendsten, A. & Ethington, R.L.(1975). Mechanical properties of 23 species of eastern hardwoods. U.S. Department of Agriculture - Forest Service Forest Products Laboratory. https://www.fpl.fs.fed.us/documnts/fplrn/fplrn230.pdf
14. Bradshaw R. I. 1997. Bamboo in Nepal, A Management Guide. www.robibradshaw.comIyer S. 2002. Guidelines For Building
15. Bradshaw R. I. 1997. Bamboo in Nepal, A Management Guide. www.robimasonhaw.com
16. Building and Construction Authority (BCA). "Delivery, Handling & Storage." BCA, 2011. Accessed September 15, 2016. https://www.bca.gov.sg/professionals/iquas/..%5CIquas%5Cgpgs%5CWEWall%5CWEWChpt4.pdf
17. Bureau of Indian Standards. 2005. Indian Standard, Common Burnt Clay Building Bricks – Specification. Bureau of Indian Standards. https://law.resource.org/pub/in/bis/S03/is.1077.1992.pdf
18. Carsan, Sammy and Christine Holding. "Growing farm timber: practices, markets and policies." Kenya: World Agroforestry Centre, 2006. Accessed September 16, 2016.
19. Chan, S. (2014). Carbon Footprint of Humanitarian Shelter: A Case Study of Relief and Construction Materials Used in Haiti. Retrieved from https://www.humanitarianlibrary.org/sites/default/files/2015/07/Carbon%20Footprint%20of%20Humanitarian%20Shelter.compressed.pdf
20. Chandrakeerthi S. R. de S. 1995. Development of Guidelines for proportioning Calicut tiled timber roof structures. Colombo: Institution of Engineers Sri Lanka. http://iesl.ceylonhost. com/IESL_publications/Civil%20Engineering/Building%20Engineering/Development%20of%20Guidelines%20for%20Proportioning%20Calicut%20Tiled%20Timber%20Roof%20 structure%20by%20S.R.De.S.%20Chandrakeerthy%20%201997.PDF
21. Chen, P.W. and Chung, D. D. L. (1996). A Comparative Study of Concretes Reinforced with Carbon, Polyethylene, and Steel Fibers and Their Improvement by Latex Addition. ACI Materials Journal.
22. Ciurileanu, G. T. & Horvath, I. B. (2012). The use of cement stabilized rammed earth for building a vernacular modern house. Buletinul Institutului Politehnic Din Iasi, 53(1).
23. Civil Engineering and Development Department, Public Fill Committee. "Guidelines for Selective Demolition and On Site Sorting." 1st ed. Hong Kong: Civil Engineering and Development Department, 2004. Accessed September 15, 2016. http://www.cedd.gov.hk/eng/services/recycling/doc/sel_dem.pdf

24. Concrete Block Association (CBA). “Aggregate Concrete Blocks: A Guide to Selection and Specification.” UK: CBA, 2007. Accessed September 15, 2016. http://www.thakeham.co.uk/images/upload/docum/Block%20Selector.pdf
25. Concrete Construction. 1983. Concrete reinforced with polypropylene fibers. https://www.concreteconstruction.net/how-to/materials/concrete-reinforced-with-polypropylene-fibers_o Accessed August 2018.
26. Consulting Engineers Association of India (CEAI), Central Public Works Department (CPWD), and Indian Building Congress (IBC).Guidelines on use of Glass in Buildings - Human Safety. 2nd ed. Confederation of Construction Products and Services (CCPS), 2009.
27. Cramer, S. M., Friday, O. M., White, R. H., and Sriprutkiat, G. (2003). Mechanical Properties of Gypsum Board at Elevated Temperatures. Proceedings of the Fire and Materials 2003 Conference.
28. Dai, Q., Kelly, J., Sullivan, J., and Elgowainy, A. (September 2015). Life-Cycle Analysis Update of Glass and Glass Fiber the for GREET Model. Retrieved from https://greet.es.anl.gov/files/glass-fiber-update
29. Department of Labour. 1995. Guidelines for the management and removal of asbestos. Wellington, New Zealand: Occupational Safety and Health Service, Department of Labour.
30. Dhir, R. K. 2002. Sustainable Concrete Construction. Thomas Telford Publishing, Thomas Telford Ltd. ISBN: 0 7277 3177 7
31. Diab, A. M., Elyamany, H. E., & Ali, A. H. (2013). Experimental investigation of the effect of latex solid/water ratio on latex modified co-matrix mechanical properties. Alexandria Engineering Journal, 52(1), 83-98. doi:10.1016/j.aej.2012.11.002
32. Division of Building and Construction Technology. 1998. A guide to good thatching practice. Cape Town, South Africa: CISIR. http://www.sa-thatchers.co.za/wp-content/
33. Fiber Reinforced Concrete Assocation. 2015. Fiber types. Retrieved from http://fiberreinforcedconcrete.org/fiber-reinforced-concrete/fiber-types/ Accessed August 2018
34. Frone, A.N., Panaitescu, D.M., Donescu, D., Spataru, C., Radovici, C., Trusca, R. & Somoghi, R. (2011) Preparation and characterization of PVA composites with cellulose nanofibers obtained by ultrasonification. BioResource Technology, 6(1).
35. Global Shelter Cluster. 2010. Reuse, recycle and disposal of emergency plastic sheets. Geneva: Global Shelter Cluster. www.sheltercentre.org/.../reuse-recycle-and-disposal-emergency-plastic
36. Government of India Ministry of Railways. Comprehensive Guide on Painting for Buildings. India: Centre for Advanced Maintenance Technology, 2007.
37. Granta Design (2017). CES Edupack Software. [online] Grantadesign.com.

38. Grégoire, G. 2007. Environmental, Health, and Safety Guidelines for Construction Materials Extraction. International Finance Corporation, World Bank Group. http://www.ifc.org/wps/ wcm/connect/a99ab8804365b27aa60fb6d3e9bda932/EHS-Guidelines+101-Webinar. pdf?MOD=AJPERES
39. Hammond, G. and Jones, C. (2008). Inventory of Carbon and Energy (ICE) Version 1.6a. http://www.organicexplorer.co.nz/site/organicexplore/files/ICE%20Version%201.6a.pdf
40. Han, J.-W., Jeon, J.-H., & Park, C.-G. (2015). Mechanical and Permeability Characteristics of Latex-Modified Pre-Packed Pavement Repair Concrete as a Function of the Rapid-Set Binder Content. Materials, 8(10), 6728–6737. http://doi.org/10.3390/ma8105339
41. Health and Environmental Development. www.cephed.org.np/pdf/31420818225.pdf
42. Home Advancement. “The Basics of Clay Tile Roof Installation.” Accessed September 15, 2016.
43. Hong Kong Building Department. Practice Note for Registered Contractors. 3rd ed. Hong Kong: Buildings Department, 2013. Accessed September 16, 2016. http://www.bd.gov.hk/english/documents/pnrc/Pnrc67.pdf
44. Hospodarova, V., Stevulova, N., Vaclavik, V., and Dvorsky, T. (2017). Influence of Cellulosic Fibers on the Physical Properties of Fiber Cement Composites. IOP Conference Series: Materials Science and Engineering, 251(1).
45. how-to-safely-remove-asbestos-code-of-practice-3561.pdf
46. http://www.engineeringcivil.com/use-of-aluminum-in-building-construction.html
47. http://www.homeadvancement.com/roof/installation/clay-tile-roofing
48. http://www.midtnlumber.com/includes/resources/flooring/installation_guide.pdf
49. http://www.waikato.ac.nz/hrm/internal/health&safety/asbestos.pdf
50. http://www.worldagroforestry.org/downloads/Publications/PDFS/b14639.pdf
51. Huang, Z., Sun, Y., & Musso, F. (2017). Assessment on bamboo scrimber as a substitute for timber in building envelope in tropical and human subtropical climate zones - part 1 hygrothermal properties test. IOP Conference Series: Materials Science and Engineering, 264, 012006. doi: 10.1088/1757-899x-264/1/012006
52. IASC Haiti Shelter Cluster, 2010. “Selection and Safe Use of Chemical Wood Protection.” Accessed September 15, 2016. https://www.sheltercluster.org/sites/default/files/docs/Timber%20treatment%20Chemical%20safe%20use%20guidance%20note.pdf
53. IFRC, UN Office for the Coordination of Humanitarian Affairs (UNOCHA) and CARE International. “A guide to the planning, use, procurement and logistics of timber as a construction material in humanitarian relief.” 1st ed. IFRC, 2009. Accessed September 15, 2016. http://reliefweb.int/sites/reliefweb.int/files/resources/D.03.c.01.%20Timber%20Guidelines-EN.pdf

54. Inter-Agency Standing Committee (IASC) and Haiti Shelter Cluster. “Reuse, recycle and disposal of emergency plastic sheets.” Accessed September 15, 2016. http://www.humanitarianlibrary.org/sites/default/files/plastic_sheeting_disposal_guidelines.pdf
55. International Federation of Red Cross and Red Crescent Societies (IFRC) and Oxfam International. Plastic Sheeting: A Guide to the Specification and Use of Plastic Sheeting in Humanitarian Relief. IFRC and Oxfam GB, 2007. Accessed September 16, 2016.
56. International Federation of Red Cross. 2007. Plastic Sheeting; A guide to the specification and use of plastic sheeting in humanitarian relief. Switzerland: International Federation of Red Cross. www.ifrc.org/PageFiles/71111/D.03.a.01.Plastic%20Sheeting_Englis.pdf
57. International Finance Corporation (IFC) World Bank Group. Environmental, Health, and Safety Guidelines for Construction Materials Extraction. Washington, DC: World Bank, 2007. Accessed September 15, 2016. http://www.ifc.org/wps/wcm/connect/d6bb0e80488551afa93cfb6a6515bb18/Final+-+Construction+Materials+Extraction.pdf?MOD=AJPERES
58. Jayasinghe C. and Kamaladasa. N. 2006. Compressive Strength Characteristics of Cement Stabilized Rammed Earth Walls. www.elsevier.com/locate/conbuildmat
59. Kandamby, T. and C. Jayasinghe. Cement Stabilized Rammed Earth For Wall Junctions of Two Storey Houses. University of Moratuwa, 2011. Accessed September 15, 2016. www.civil.mrt.ac.lk/conference/raghu/26.pdf
60. Kariyawasam, K.K.G.K.D. and Jayasinghe, C. (2016). Cement stabilized rammed earth as a sustainable construction material. Construction and Buildings Materials, 105, 519-527. https://www.sciencedirect.com/science/article/pii/S0950061815308606
61. Lu, J., Wang, T., & Drzal, L. T. (2008). Preparation and properties of microfibrillated cellulose polyvinyl alcohol composite materials. Composites Part A: Applied Science and Manufacturing, 39(5), 738-746. doi:10.1016/j.compositesa.2008.02.003
62. Maharashtra Pollution Control Board. 2006. Guidelines for Environmentally Sound Operations for Stone Quarries. Mumbai: Mahrashtra Pollution Control Board. http://mpcb.gov.in/ereports/pdf/GUIDELINES%20FOR%20STONE%20QUARRYING.pdf
63. Maïni S. 2009. Earthen Architecture for Sustainable Habitat and Compressed Stabilized Earth Block Technology. http://www.ada.gov.sa/idc/groups/public/documents/ar_ada_researches/004568.pdf
64. Mello, E., Ribellato, C., and Mohamedelhassan, E. (2014). Improving Concrete Properties with Fibers Addition. International Journal of Civil and Environmental Engineering, 8(3).
65. Merkley, D.J. & Luo, C. (2000). U.S. Patent No. US6872246B2. James Hardie Research Pty Ltd.

66. Miller, Frank, Taylor, Rodney, and George White. Best Practices for Keeping Illegally Harvested Timber Out of Your Supply Chain. 1st ed. WWF, 2006. Accessed September 16, 2016. http://gftn.panda.org/?82060/Keep-it-legal-Best-Practices-for-Keeping-Illegally-Harvested-Timber-Out-of-Your-Supply-Chain-English-Chinese#
67. Minke, G. (2005). Building with earth: Design and technology of a sustainable architecture. Birkhauser.
68. Moropoulou, A., et.al. (2011). "Life Cycle Analysis of Mortars and its Environmental Impact." MRS Proceedings. 895. 10.1557/PROC-0895-G06-02.
69. Mundra, S., Sindhi, P.R., Chandwani, V., Nagar, R., Agrawal, V. (2016). Crushed rock sand - An economical and ecological alternative to natural sand to optimize concrete mix. Perspectives in Science, 8, 345-347. doi:10.1016/j.pisc.2016.04.070
70. National Wood Flooring Association (NWFA). Wood Flooring Installation Guidelines and Methods. 2nd ed. NWFA, 2012. Accessed September 16, 2016.
71. Nebel, B., Zimmer, B., and Wegener, G. (2004). Life Cycle Assessment of Wood Floor Coverings - A Representative Study for the German Flooring Industry (11 pp). The International Journal of Life Cycle Assessment, 11(3), 172-182. doi: 10.1065/lca2004.10.187
72. Nehvi, R., P. Kumar, and U. Z. Nahvi. 2016. Effect of different percentages of polypropylene fiber (Recron 3s) on the compressive, tensile, and flexural strength of concrete. International Journal of Engineering Research & Technology (IJERT) 5(11): 124-130
73. Nepal Standards Institute. 2003. Specifications for Galvanized Corrugated Sheet. Kathmandu: Nepal Standards Institute. http://nbsm.gov.np/file/download/file1712045347.pdf
74. Occupational Safety and Health Branch Labour Department. "Guidance Notes on Health Hazards in Construction Work." Accessed September 15, 2016. http://www.labour.gov.hk/eng/public/oh/OHB82.pdf
75. Occupational Safety and Health Service (OSHS). "Guidelines for the Management and Removal of Asbestos." 2nd ed. Wellington: OSHS, 1999.
76. Pacheco-Togal, F. and Jalali, S. (2011). Cementitious building materials reinforced with vegetable fibers: A review. Construction and Building Materials, 25(2), 575-581. https://doi.org/10.1016/j.conbuildmat.2010.07.024
77. Perera, A.A.D.A.J. "Innovations, Applications and Standards of Compressed Stabilized Earth Blocks." University of Moratuwa, 2007. Accessed September 15, 2016. www.irbnet.de/daten/iconda/CIB15593.pdf
78. Portland Cement Association. "Recycled Aggregates." PCA, 2016. Accessed September 15, 2016. http://www.cement.org/for-concrete-books-learning/concrete-technology/concrete-design-production/recycled-aggregates
79. Practical Action. "Non Poisonous Timber Protection." United Kingdom: Practical Action, n.d. Accessed September 15, 2016. http://practicalaction.org/media/preview/13104
80. Pretoria Division of Building and Construction Technology. "A Guide to Good Thatching Practice." Pretoria: The Division of Building and Construction Technology, 1998.

81. Qiang, L. & Liping, T. (2017). Engineering properties of unstabilized rammed earth with different clay contents. Journal of Wuhan University of Technology-Mater. Sci. Ed., 32(4), 914-920. doi:10.1007/s11595-017-1690-y

82. r Bank for Reconstruction and Development. 2014. Sub-sectoral Environmental and Social Guideline: Quarrying. European Bank for Reconstruction and Development. www.ebrd.com/downloads/policies/environmental/mining/stone-sand.pdf

83. Rahmanian, I. (2011). Thermal and mechanical properties of gypsum boards and their influences on fire resistance of gypsum board based systems. https://www.escholar.manchester.ac.uk/api/datastream?publicationPid=uk-ac-man-scw:137521&datastreamId=FULL-TEXT.PDF

84. Rathi, M.K. and Ajinkya K. Patil. “Use of Aluminum in Building Construction.” Civil Engineering Portal. Accessed September 16, 2016.

85. Reddy, B.V., and Jagadish, K. (2003). Embodied Energy of Common and Alternative Building Materials and Technologies. Energy and Buildings, 35(2), 129-137. Retrieved from https://www.sciencedirect.com/science/article/pii/S0378778801001414

86. Rietz, Raymond C. Storage of Lumber. Washington, DC: U.S Department of Agriculture and Forestry, 1978. Accessed September 16, 2016. http://www.esf.edu/wus/documents/StorageOfLumberFPL531.pdf

87. Riza, F. V., Rahman, I. A., & Zaidi, A. M. A. (2010). A Brief Review of Compressed Stabilized Earth Brick (CSEB). 2010 International Conference on Science and Social Research.

88. Safe Work Australia. 2011. How to Safely Remove Asbestos: Code of Practice. Sydney: Safe Work Australia. http://www.workcover.nsw.gov.au/__data/assets/pdf_file/0016/15217/

89. Safe Work Australia. How to Safely Remove Asbestos, Code of Practice. NSW, 2011. Accessed September 16, 2016. http://www.safework.nsw.gov.au/__data/assets/pdf_file/0015/50082/how-to-safely-remove-asbestos-code-of-practice-3561.pdf

90. Sah R. C. and Yadav K. 2010. Study of Lead in Paints in Nepal. Kathmandu: Center for Public

91. Salam K. and Pongen Z. 2008. Hand Book on Bamboo. Guwahati, India: Cane and Bamboo Technology Centre.

92. Shah, D.U., Bock, M.C., Mulligan, H., & Ramage, M.H. (2015). Thermal conductivity of engineered bamboo composites. Journal of Materials Science, 51(6), 2991-3002. doi:10.1007/s10853-015-9610-z

93. Sharma, B., Gatoo, A., Bock, M., & Ramage, M. (2015). Engineered bamboo for structural applications. Construction and Building Materials, 81, 66-73. doi:10.1016/j.conbuildmat.2015.01.077

94. Sharma, B., Gatoo, A., Bock, M., & Ramage, M. (2015). Engineered bamboo for structural applications. Construction and Building Materials, 81, 66-73. doi:10.1016/j.conbuildmat.2015.01.077

95. Shelter Cluster Nepal. “Corrugated Galvanised Iron (CGI) Specifications for Roofing.” Accessed September 15, 2016. https://www.sheltercluster.org/sites/default/files/docs/cgi_specification_150708.pdf

96. Shelter Cluster Nepal. 2015. Technical and Implementation Modalities Guidance Document

97. Shokrieh, M.M., Mahmoudi, A. and Shadkam, H.R. (2015). Hybrid Polyvinyl Alcohol and Cellulose Fiber Pulp Instead of Asbestos Fibers in Cement-Based Composites. Mechanics of Composite Materials, 51(2). https://link.springer.com/content/pdf/10.1007/s11029-015-9494-7.pdf

98. Sikora, P., Horszczaruk, E., Skoczylas, K., & Rucinska, T. (2017). Thermal Properties of Cement Mortars Containing Waste Glass Aggregate and Nanosilica. Procedia Engineering, 196, 159-166. doi:10.1016/j.proeng.2017.07.186

99. Singh, S. K. (2011). Polypropylene Fiber Reinforced Concrete: An Overview. New Building Materials & Construction World.

100. Society for Excellence in Habitat Development, Environment Protection, and Employment Generation. 2009. Environmentally friendly Indian building material technologies for cost effective housing. https://www.unido.org/sites/default/files/2009-04/Environment_friendly_Indian_building_material_technologies_for_cost_effective_housing_0.pdf

101. Soydan, A.M., Sari, A.K., Duymaz, B., Akdeniz, R., and Tunaboylu, B. (2018). Air Cured Fiber-Cement Composite Mixtures with Different Types of Cellulose FIbers. Advances in Materials Science and Engineering. https://doi.org/10.1155/2018/3841514

102. State of California Department of Transportation. “Construction Site Best Management Practice (BMP) Field Manual and Troubleshooting Guide.” Caltrans, 2003. Accessed September 15, 2016. http://www.dot.ca.gov/hq/construc/stormwater/BMP_Field_Master_FullSize_Final-Jan03.pdf

103. Sudha, C., Ravichandran, P.T., Krishnan, K.D., Rajkumar, P.R.K., Anand, A. (2016). Study on Mechanical Properties of High Performance Concrete using M-Sand. Indian Journal of Science and Technology, 9(5). doi: 10.17485/ijst/2016/v9i5/87262

104. Tan, B., Ching, Y., Poh, S., Abdullah, L., & Gan, S. (2015). A Review of Natural Fiber Reinforced Poly(Vinyl Alcohol) Based Composites: Application and Opportunity. Polymers, 7(11), 2205-2222. doi:10.3390/polym7111509

105. Termite Control by Do it yourself Pest Control. “Termite Chemical Treatments for Termite Control.” Accessed September 16, 2016. http://www.doityourselftermitecontrol.com/chemical-termite-treatments.html

106. Thirumalini, S., Ravi, R., & Rajesh, M. (2018). Experimental investigation on physical and mechanical properties of lime mortar: Effect of organic addition. Journal of Cultural Heritage, 31, 97-104. doi:10.1016/j.culher.2017.10.009

107. Tonoli, G.H.D., Rodrigues Filho, U. P., Savastano Jr., H., Bras, J., Belgacem, M.N., and Rocco Lahr, F.A. (2009). Cellulose modified fibers in cement based composites. Composites Part A: Applied Science and Manufacturing, 40(12), 2046-2053. https://doi.org/10.1016/j.compositesa.2009.09.016

108. Traditional and Sustainable Building. General Guidelines for Working with Lime Mortar and Limewash. Traditional and Sustainable Building, 2007. Accessed September 16, 2016. http://www.johngreenwaltlee.com/battersea/battersea/2010_Daily_Logs/Entries/2010/8/10_Small_Mortar_Match_Tests_in_Place_files/Lime_Use_Guide-2.pdf

109. United Nations Environment Program (UNEP). “Sand, rarer than one thinks.” UNEP Global Environmental Alert Services, March, 2014. Accessed September 15, 2016. http://www.unep.org/pdf/UNEP_GEAS_March_2014.pdf

110. United States Bureau of Reclamation (USBR). “Standards for Material Handling, Storage, and Disposal, Section 11.” USBR, 2009. Accessed September 15, 2016. http://www.usbr.gov/ssle/safety/RSHS/sec11.pdf

111. uploads/2010/09/AGuideToGoodThatchingPractice.pdf

112. US General Services Administration (GSA). General Guidelines for Painting Exterior and Interior Surfaces. Washington, DC: GSA, 2012. Accessed September 16, 2016. http://www.gsa.gov/portal/content/112254

113. US6872246B2 - Fiber Cement Composite Materials Using Cellulose FIbers Loaded with Inorganic and/or Organic Substances. October 4, 2000. https://patents.google.com/patent/US6872246B2/en

114. Vigel, U. & Kams, M. (2011). Thermal conductivity of thatched (reed) roof in composite ceiling. Civil Engineering. International Scientific Conference. Proceedings (Latvia). "

115. Vilder, I. D., Buyle, G., Virgo, V., Gijsbers, R. (2016). Membranes for shelters - A comparative study to assist humanitarian workers in selecting suitable textile materials. SpeedKits.

116. Waziri, B.S., Lawan, Z.A., and Mala, M. (2013). Properties of Compressed Stabilized Earth Blocks (CSEB) For Low-Cost Housing Construction: A Preliminary Investigation. International Journal of Sustainable Construction Engineering & Technology, 4(2), 40.

117. Woubishet Zewdu Taffese and Kassahun Admassu Abegaz, *Buildings* **2019**, p. 136